SEWAGE WORKS JOURNAL

ANNUAL CONVENTION NUMBER

VOL. XXI SEPTEMBER, 1949 No. 5

Special Features

Bio-Precipitation of Sewage—Okun

B.O.D. of Sewage in Sea Water—Gotaas

Anaerobic Industrial Waste Treatment—Gehm

Treatment of Soluble Oil Wastes—Haseltine

Disposal of Radioactive Wastes—Ruchhoft

Sewage Works Equipment and Supplies Directory

Twenty-Second Annual Meeting—Oct. 17–20, 1949
Hotel Statler, Boston, Mass.
(See Page 931)

OFFICIAL PUBLICATION OF THE

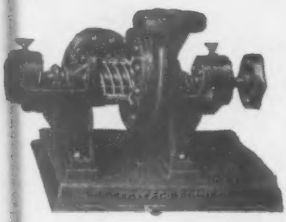
FEDERATION OF SEWAGE WORKS ASSOCIATIONS

why

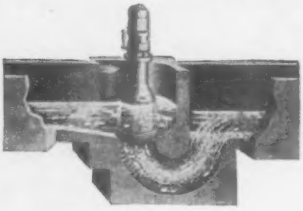
OPERATORS PREFER and ENGINEERS SPECIFY

Equipment that is planned to do the job . . . based on the experience gained over a period of many years, is naturally going to work well, require a minimum of maintenance and be simple to operate. These factors . . . which are of prime importance to the men who operate sewage treatment plants . . . are built into Chicago equipment as a result of hundreds of continuing studies of the needs and problems of the men who actually *use* the Comminutors, Scru-Pellers, Swing Diffusers and other Chicago Sewage equipment. *"The satisfaction of the operator with this equipment was nearly universal."

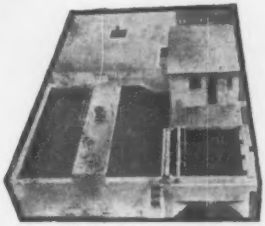
*Sewage Works Journal, September 1946, p. 871



SCRU-PELLER SLUDGE PUMPS: Specifically developed for the difficult duty of pumping heavy primary sludge, the Scru-Peller Pump has built-in features that permit it to do this work without undue strain on any part. Screw-feed, continuous-multiple shearing cuts stringy solids that would clog other pumps. Ball-bearings on both sides of the impeller provide perfect balance and prevent vibration and strain on the shaft under load.



COMMINUTORS: The Comminutor eliminates sewage screenings handling and disposal with its accompanying foul odors, fly nuisance and unsightliness. Installed in the influent channel it automatically screens and cuts sewage solids without removal from the line of flow. Comminuted particles settle rapidly with primary sludge. Comminutors installed in lift stations and before pumps in plants prevent pump clogging, simplify maintenance.

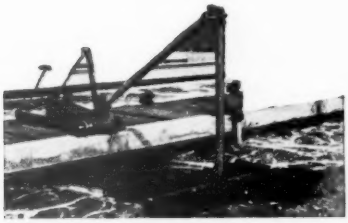


"PAKAGE" SEWAGE PLANTS: Flexibility is the design keynote in the "Pakage" plant. Not a cut-down version, but planned and developed for the smaller community, housing development, airport or industrial plant. Populations from 100 to 5000 can be served with these plants. Simple to operate, odorless, with no fly nuisance, producing a sparkling clear effluent, they can be located near dwellings without creating a problem.

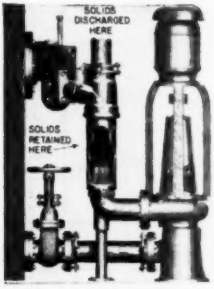
"CHICAGO" EQUIPMENT

The engineer who specifies sewage treatment equipment recognizes these facts. Acceptance by operators is the true seal of approval. Sewage equipment must stand the test of time . . . must continue to function well year after year. To assure continuous, efficient, economical operation, specify Chicago equipment . . . with the certainty that it will do the job.

Boston Sewage Works Convention,
October 17-20, 1949.
Booths 44-47



SWING DIFFUSERS FOR AERATION TANKS: For the larger Activated Sludge Sewage treatment plants the Chicago Wide Band Air Diffusion System with swing diffusers provides optimum tank circulation without center coring. The wide band of fine bubbles allows greater contact between air and mixed liquor, providing greater oxygen absorption. The units can be raised to the tank walk for cleaning, replacement or rearrangement of tubes. Installed in over 100 sewage treatment plants; for industrial waste treatment; and in chemical process industries.



FLUSH-KLEEN SEWAGE EJECTORS: Actual clog-proof pumping of raw sewage or any liquid containing coarse and stringy matter is attained by the Flush-Kleen because a screen in the influent pipe protects the impeller from all solids. Incoming solids are retained on the screen and as the pump starts the screen is backwashed as the solids are carried out the discharge pipe.

AIR-CONTROL GRIT CHAMBER: The Air-Control grit chamber with swing diffusers is a development of the Chicago Pump Company which operates independent of the velocity of sewage flow. Located before comminutors or pumps it removes all inorganic matter, producing a remarkably clean grit. This is effected by setting up spiral flow in a small aeration-type tank, at a speed which produces a washing action allowing the inorganics to drop out while lighter organics remain suspended. Grit removal saves wear on pumps and equipment . . . eliminates much costly maintenance.

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SEWAGE EQUIPMENT DIVISION

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SEWAGE WORKS JOURNAL

REG. U. S. PAT. OFF.

A bimonthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

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Prince and Lemon Sts., Lancaster, Pa.

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Members of local sewage works associations affiliated with the Federation, $3.00 per year.

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Entered as second-class matter, May 7, 1934, at the post office at Lancaster, Pa., under the Act of March 3, 1879. Accepted for mailing at the special rate of postage provided for in the Act of February 28, 1925, embodied in part 4, Section 538, P. L. & R., authorized October 4, 1945.

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Sewage Works Journal is indexed regularly by *Industrial Arts Index* and *Engineering Index.*

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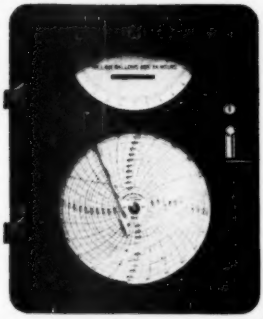
most accurate yet developed within its flow range



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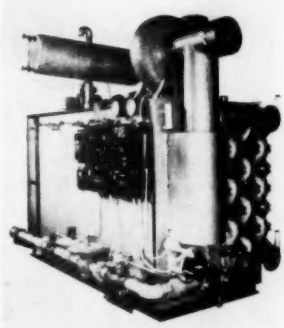

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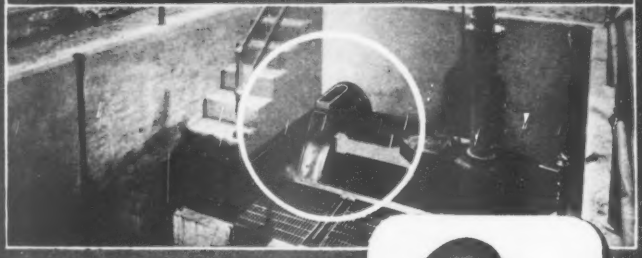
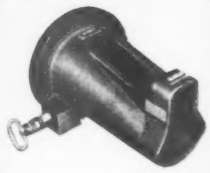


The attractive plant of the Belgrave Sewer District was engineered by Thomas M. Riddick and built under the direction of H. O. Johnson, Superintendent. Outstanding both in appearance and operation, the sewage treatment works serves a growing residential and manufacturing community of 8,000 persons. Builders Kennison Nozzles meter the incoming sewage and with other Builders instruments contribute to the high performance of the plant. For engineering data and bulletins describing Builders sewage works equipment, address Builders-Providence, Inc., (Division of Builders Iron Foundry), Providence 1, R. I.



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2—16" Kennison Nozzles
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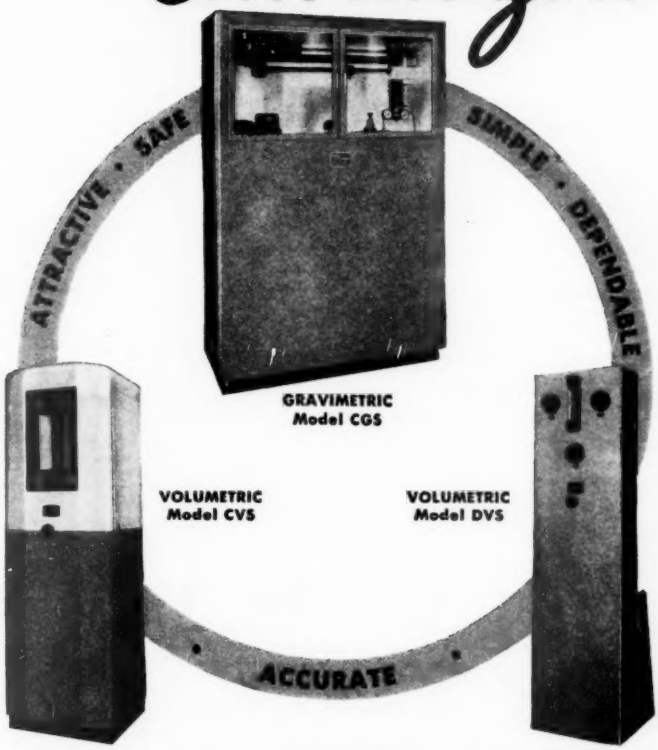

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SCREENS · COLLECTORS · MIXERS · AERATORS

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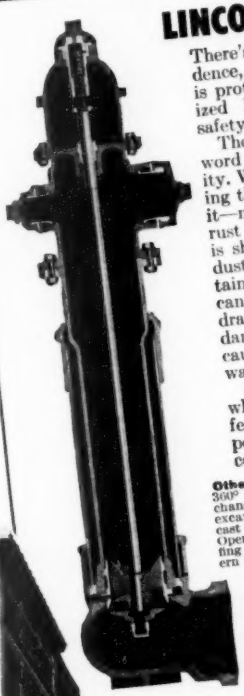
"One of America's Safest Cities" The Mathews Firemen Say



There's good reason for their confidence, because Lincoln, Nebraska is protected by Mathews Modernized Hydrants—and that means safety *plus*.

These great hydrants are the last word in simplicity and serviceability. Water cannot reach the operating thread—no risk of ice jamming it—no risk of deterioration from rust or sediment. The revolving nut is shielded against rain, snow and dust. All working parts are contained in a removable barrel which can be replaced in a jiffy if the hydrant is broken by a truck. And the damaged hydrant cannot leak, because the main valve opens *against* water pressure.

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Other Mathews Features: Head can be turned 360° • Replaceable head, nozzle outlets easily changed • Nozzle levels raised or lowered without excavating • Protection case of "Sand-Spun" cast iron for extra strength, toughness, elasticity • Operating thread only part to be lubricated • Stuffing box cast integral with nozzle section • A modern barrel makes any Mathews good as new

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Made by R. D. WOOD COMPANY

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Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves

Operating results attest overall efficiency . . . . . of →

YEOMANS *Spiraflo* CLARIFIER with tangential inlet

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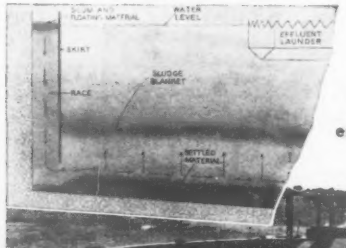
- Sewage enters the main clarification compartment at the bottom, after having spiraled through an annular race around the periphery of the tank
- Scum, grease oil and floatable materials are automatically removed from the annular race—therefore cannot pass on to the filter and clog distributor nozzles
- Raw sewage flows upward through a sludge blanket toward centrally located effluent weirs—increases flocculation and removal of solids
- Construction costs are minimized because of straight-wall design and elimination of costly reinforced concrete effluent troughs
- Pre-aeration can be accomplished inexpensively by installing air diffusion tubes in the race

Spiraflo clarifiers can be installed in water treatment and in either trickling filter or activated sludge sewage treatment plants. A highly efficient overall plant reduction is achieved when the Spiraflo is used in conjunction with the "Aero-Filter" high capacity trickling filter system. Spiraflo clarifiers are the logical choice for primary treatment plants, especially those treating strong industrial wastes.

Bulletin 6790 contains full information with performance data and construction cost estimates—write us for it.



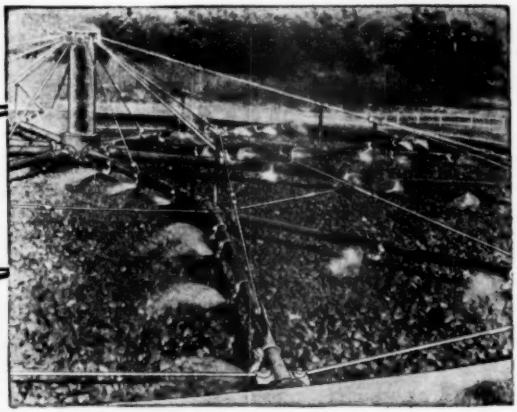
YEOMANS

YEOMANS BROTHERS COMPANY, 1411 North Dayton Street, Chicago 22, Illinois

HIGH LOADING

ECONOMY OF SPACE

LOW OPERATING COST



...recommend

YEOMANS "Aero-Filter"

★ A HIGH-CAPACITY BIOLOGICAL TRICKLING FILTER IDEAL FOR TREATING STRONG INDUSTRIAL WASTES ★ CAN BE FITTED TO ANY REQUIREMENTS—FROM SMALL UNITS TO LARGE TREATMENT WORKS

In more than 100 installations the Yeomans "Aero-Filter" is establishing remarkable records for unusually high purifying efficiency at exceptionally low cost.

Single stage operation of "Aero-Filters" produces a clear effluent, and reductions of raw sewage BOD ranging from 80 to 85 percent are common; while two-stage operation is regularly achieving BOD reductions of 90 to 94 percent.

Construction cost is exceedingly low because the "Aero-Filter" bed is only about one-eighth the size required for a standard rate filter of equal capacity; and because an oversize primary tank is not required, since all returns are made direct to the filter. Also, rain-drop distribution eliminates all need for costly recirculation for dilution purposes. Operating cost is the lowest among all types of complete sewage treatment.

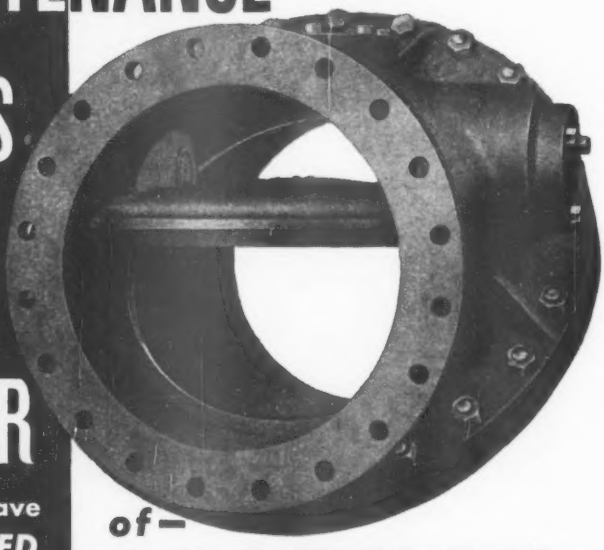
The "Aero-Filter" can be fitted to any requirements. Accurate cost estimates and complete engineering data are readily obtainable. Write for Bulletin 6570.

YEOMANS BROTHERS COMPANY • 1425 N. Dayton Street • Chicago 22, Illinois

YEOMANS

MAINTENANCE COSTS ARE LOWER

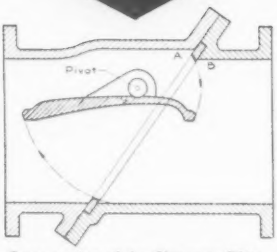
when you have *CUSHIONED CLOSING*



of—

CHAPMAN CHECK VALVES

TILTING DISC



Cross-section of the Chapman Tilting Disc Check Valve illustrating the way that the balanced disc is supported on the pivot, with arrows showing the travel of the disc. A feature of the design is that the disc seat lifts away from the body seat when opening, and drops into contact when closing, with no sliding or wearing of the seats.

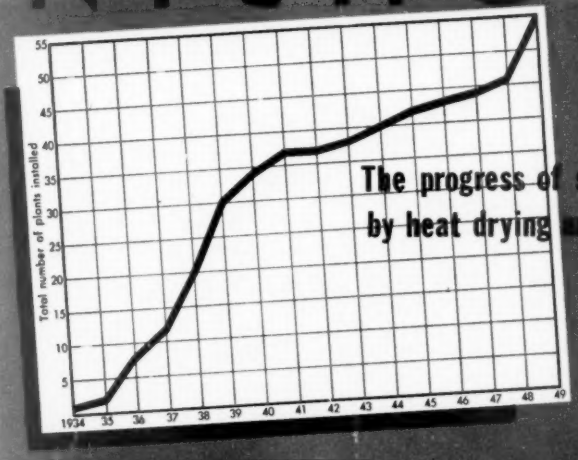
That's right! Maintenance costs *are lower* with Chapman Check Valves . . . lower because the balanced disc works *with the stream*. There's no slamming to cause destructive pipe line stresses and increase maintenance costs. Nor is there any rubbing on seats . . . the disc closes quickly and quietly with no sliding or wearing action.

Yet that's only half the story. Head losses are actually 65% to 80% lower than for conventional type check valves. And, when used on pump discharge lines, substantial power savings are possible.

Why not write today for engineering data and reports of tests.

THE CHAPMAN VALVE MFG. COMPANY
INDIAN ORCHARD, MASSACHUSETTS

NICHOLS



The progress of sludge disposal by heat drying and incineration

Included in the graph at left are all reported installations by every manufacturer of sewage sludge incineration during the past 15 years, 1934 to 1949.

The graph shows the rise in the use of heat drying and incineration for the disposal of sewage sludge over the past 15 years. While progress was slowed down somewhat during the war years, installations from 1945 to the present indicate an increased interest in and acceptance of the use of heat drying and incineration by American municipalities.

65%

NICHOLS installations

35%

Those of all other Mfrs.

In the overall field of sewage sludge disposal by . . .

incineration to sterile ash

heat drying for fertilizer and

combination drying or incineration . . .

it is worth remembering that 65% of the contracts awarded by municipalities have been to Nichols Engineering & Research Corporation. THERE MUST BE A REASON.

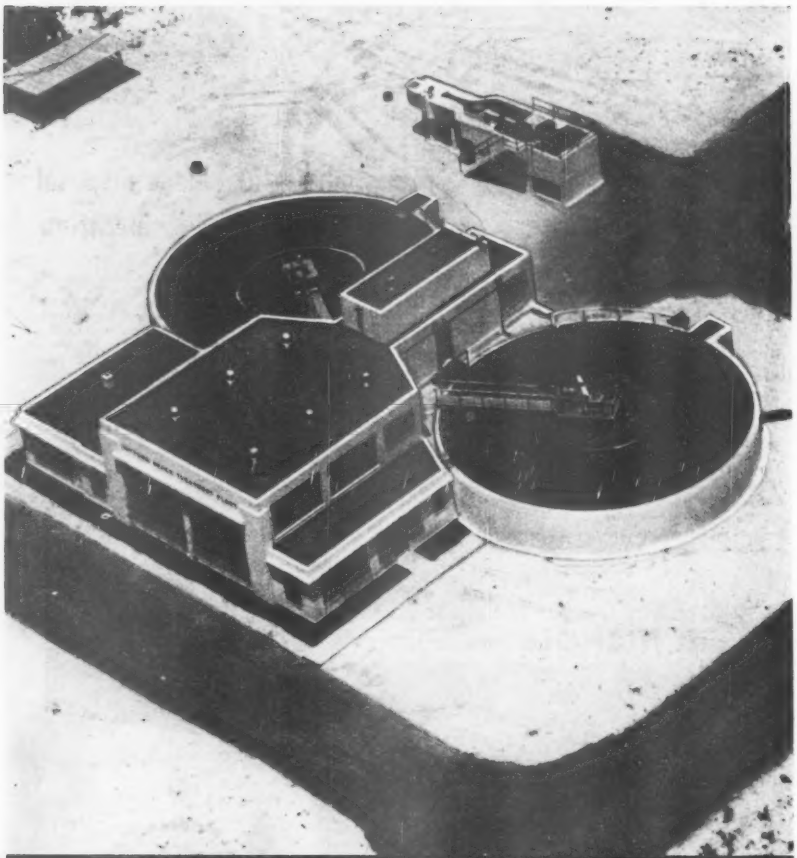
We will gladly send you Bulletin No. 201B

Nichols ENGINEERING & RESEARCH CORPORATION

70 PINE ST., NEW YORK 5, N. Y.

611 S. Los Robles Ave., Pasadena, Calif. • 1477 Mountain St., Montreal 25, Canada

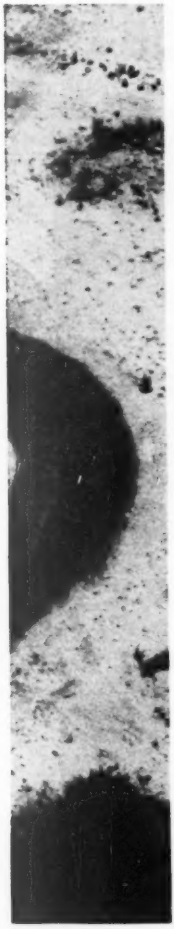
*NEW *ECONOM



ORIGINAL INSTALLATION OF THE INFILCO "DAYTONA BEACH PROCESS" AT DAYTONA BEACH, FLORIDA, WHERE THE EFFICIENCY AND ECONOMY OF THIS TREATMENT METHOD IS BEING DEMONSTRATED IN EVERY DAY USE.

* *While you are at the Convention (October 17-20), drop in at our Booth. We'll be pleased to explain in more detail about these latest developments in waste treatment. There will also be information on other types of INFILCO equipment and processes of importance to all concerned with sewage works planning and operation.*

ICAL * PROVEN *



CHEMICAL *and* BIOLOGICAL SOLUTIONS TO WASTE TREATMENT

Two remarkable adaptations of the ACCELATOR® are now available for the treatment of many wastes by either chemical or biological methods, or by varying combinations of the two.

Thoroughly tested in laboratory and pilot plant studies . . proved out in actual use . . these remarkably simple yet effective methods may provide the waste treatment answer you have long sought.

* THE INFILCO "DAYTONA BEACH PROCESS" . . *for the clarification and treatment of oil refinery wastes, organic wastes, and domestic sewages.*

Using a Sewage Accelator with Vorti-Mix Aeration, this method of waste treatment is based upon the ability of water softening plant sludge (or other similar material) to remove oils, greases and other colloidal organic matter.

* AERO-ACCELATOR . . *for high rate "activated slurry" biological treatment of food processing wastes, other organic wastes, and domestic sewages.*

The AERO-ACCELATOR with Vorti-Mix Aerator incorporates intensive aeration with Accelator type circulation for rapid biological action. Incoming sewage or liquid waste is immediately dispersed along with oxygen or air throughout the entire mass of "activated slurry". Retention time is much less than in conventional biological treatment methods.

* AERO-ACCELATOR combined with the INFILCO "DAYTONA BEACH PROCESS" . . *for biological—chemical treatment where shock loads of incoming wastes of varying organic composition are frequent.*

When an AERO-ACCELATOR with Vorti-Mix Aerator is used with the addition of a small amount of calcium carbonate or softening plant sludge to weight the "activated slurry", the combined biological-chemical approach gives better separation of clarified liquid and a more compact sludge. Consequently shock loads may be handled with less possibility of upsetting the treatment process.

INFILCO

• BETTER WATER CONDITIONING AND WASTE TREATMENT SINCE 1894 •

INFILCO INC.

SALES OFFICES IN TWENTY SIX PRINCIPAL CITIES

WORLD'S LEADING MANUFACTURERS OF WATER CONDITIONING AND WASTE TREATING EQUIPMENT

40 Years of Protection

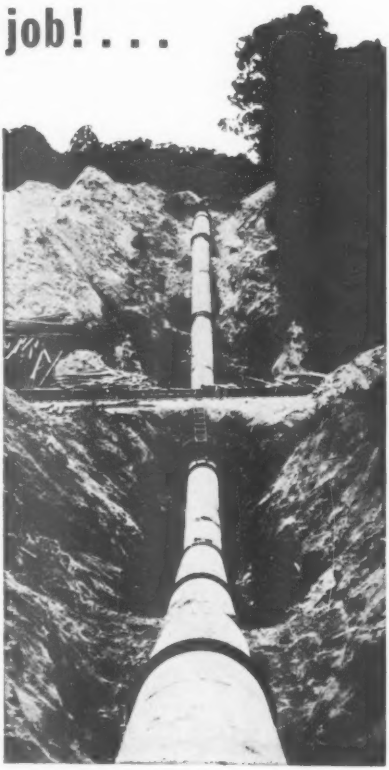
earned Koppers Bitumastic this job! . . .

In 1948—when the city of Springfield, Mass., met increasing demands for water with 26,000 feet of new 48-inch line — Koppers Bitumastic® 70-B Enamel was specified as an interior and exterior protective coating. With good reason, too, for Springfield engineers had first-hand knowledge of the long-lasting protection of Koppers Bitumastic.

In 1909, when Springfield's Westfield Little River System was started, seven miles of 42-inch line were coated with Koppers Bitumastic. For 40 years, the Bitumastic Coating has kept flow capacity high and guarded the line against corrosion. Other lines, laid in 1929 and 1943, also are protected by Bitumastic.

Inside the pipe, the glass-smooth, high-gloss surface of Koppers Bitumastic Enamel forms a barrier against tuberculation, rust and corrosion. Bitumastic keeps water from touching the underlying steel pipe surfaces . . . protects against the corrosive action of soil chemicals . . . has high electrical resistance. And it won't deteriorate with age.

If you're planning a water or sewage line, turn the coating job over to engineers of Koppers Contract Department. They'll handle it from start to finish, assuring long-lasting protection for the project. Write for complete information on Koppers Contract Service.



Springfield's new 48-inch line is shown crossing beneath railroad tracks through 72-inch pipe placed in an open cut. The new steel line, like others in the Springfield system, is protected with Koppers Bitumastic Enamel.

KOPPERS BITUMASTIC ENAMELS

KOPPERS COMPANY, INC., Dept. 919T, Pittsburgh 19, Pa.

Bulletin on

POROUS MEDIA

by **CARBORUNDUM**

TRADE MARK

NO. 3 SEPTEMBER, 1949

Meeting Requirements of Successful Air Diffusion

Recent experiences at many activated sludge plants have pointed to a cogent fact: *that ceramically bonded-porous diffusers of the ALOXITE aluminum oxide type continue to prove their ability to meet the peculiar and difficult requisites of the process!* This is vital when considering the further fact that air diffusers comprise the single most important equipment or design factor affecting overall efficiency.

Even when the process was introduced 25 years ago, it became apparent that there were two opposing diffuser requirements:

1. Small pore material to discharge minimum size air bubbles for maximum oxygen absorption while simultaneously performing the major function of mechanical air lift;
2. Sufficiently large pores to avoid early clogging from either air side or liquor side.

An adequate balance between these conflicting points was originally established with porous ceramic media. Improvement in this balance has been steady throughout the period of use because pore size and other product characteristics are controllable. *In the past many other materials and equipment ideas were tried but have proved inadequate.*

ALOXITE diffuser plates and tubes meet the further important requirements of uniformity and freedom from corrosion, erosion or strength deterioration. Because they are time-tested and proved in meeting *all* requirements and specifications, they are now the ideal media for successful aeration.

Properties of ALOXITE Porous Media

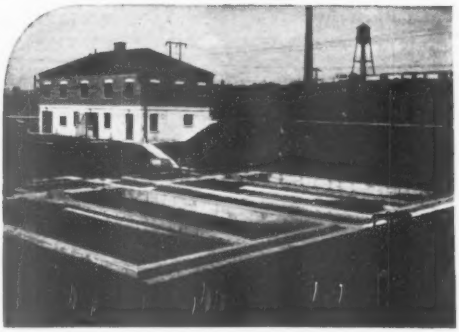
MATERIAL	Ceramically bonded crystalline aluminum oxide grain of controlled sizes.
GRADES (Pore size)	**Filter Underdrains**... coarse and very coarse. **Direct Filtration**... range from very fine to medium. **Diatomite Support**... range from fine to medium. **Air (gas) Diffusion**... range from fine to coarse (permeability from 10 to 120.)
SOLUBILITY	**In Water and Air**... insoluble at all normal operating temperatures. **In Acids**... generally resistant at all operating temperatures, except to hydrofluoric acid. **In Alkaline Solutions**... ceramic bonds are progressively soluble with time and temperature increases.
STRENGTH	Transverse breaking strength is relatively good ranging from 1000 lbs./sq. in. (coarse grades) to 3000 lbs./sq. in. (fine grades).
REFRACTORINESS	All grades withstand up to 900° C. without softening.
THERMAL SHOCK RESISTANCE	Withstand changes up to 20° C./hr. (Where more severe heat shock exists, ceramically bonded silicon carbide porous media are available.)
POROSITY	Ratio of pore volume to total volume of all grades approximately 35%.
WEIGHT	Approximately 0.09 lbs./cu. in.

TECHNICAL DATA on porous media and their application is available on request. You may obtain any or all of the following engineering bulletins by writing Dept. P-99. No. 1—Aeration of Sewage and Water. No. 2—Underdrain Systems for Filters and Softeners. No. 3—General Catalog information.

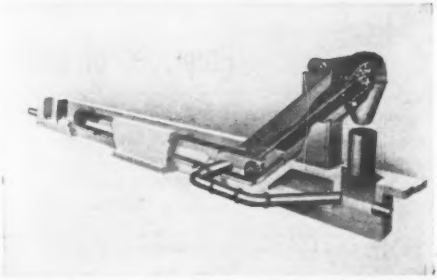
THE CARBORUNDUM COMPANY • Refractories Division • **PERTH AMBOY, N. J.**

"Carborundum" and "Aloxite" are registered trademarks which indicate manufacture by The Carborundum Company

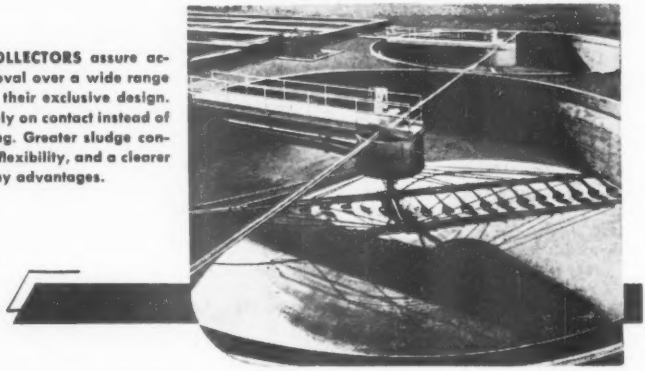
It's a Matter of Record...



REX CONVEYOR SLUDGE COLLECTORS combine the well-known advantages of the rectangular settling tank with a rugged and efficient form of sludge removal mechanism. Whether handling primary sludge or light flocculent solids, their performance is efficient and economical. They rarely need to be operated more than a few hours a day.



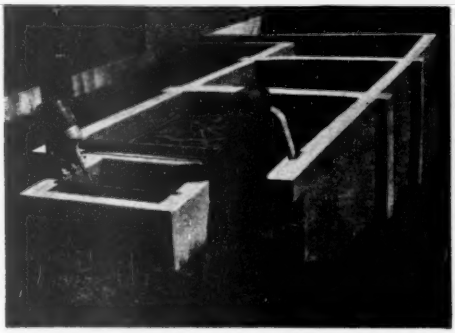
REX GRIT EQUIPMENT with its exclusive recirculating principle, effectively separates and removes inorganic solids from liquids. No grit washer is required. Rugged construction assures long, economical service.

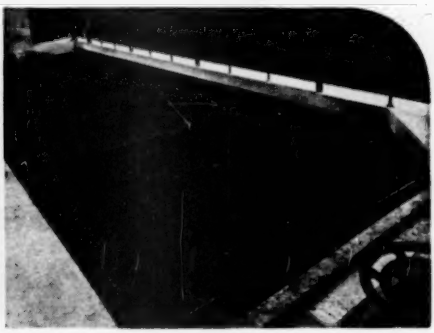


REX TOW-BRO SLUDGE COLLECTORS assure accurate control of sludge removal over a wide range of withdrawal rates through their exclusive design. Sludge is removed immediately on contact instead of the usual plowing or scraping. Greater sludge concentration, greater operating flexibility, and a clearer effluent are a few of the many advantages.

. . . and in plant after plant, the records show that Rex Sanitation and Process Equipment provides unequaled efficiency . . . sets the standards for economical, long-life operation.

Whether it's a large plant or small, a look at the figures will convince you that Rex Equipment is right for your operation . . . primary or complete treatment . . . domestic or industrial waste. Specially trained Rex Sanitation Engineers will be happy to assist you with your individual problems. For all the facts, write for your copy of Bulletin No. 48-41. Chain Belt Company, 1606 West Bruce Street, Milwaukee 4, Wis.





REX SLO-MIXERS AND FLASH MIXERS assure rapid disbursement of chemical throughout the liquid, followed by a gentle, multi-stage slow mixing for optimum floc formation. Rex Slo-Mixers assure positive mixing, eliminate short-circuiting and effect important savings in chemicals.

REX VERTI-FLO delivers a highly clarified effluent with an extremely short detention period. It provides maximum tank capacity for any desired tank size and maximum practical weir length. The combination of large weir length and low vertical velocities assures a clearer effluent, for greater capacity at minimum cost.

REX MECHANICALLY CLEANED BAR SCREENS AND TRITURATORS are neat, streamlined units that provide an efficient means of removing large solids from liquids and reducing them in size. Reduced material is returned into the sewage flow for quick and efficient handling in settling tanks and digesters.

CHAIN BELT REX COMPANY

SANITATION EQUIPMENT

Cutting Sewer Costs IS LIKE PLAYING GOLF

"Matched clubs" mean better results for the golfer. In building sewers your "matched set" of ARMCO Corrugated Metal Structures means you get exactly what you need to do the job. Here's how it works to save you time, money and labor . . .

You select plain, galvanized ARMCO Corrugated Metal Pipe for normal service. ASBESTOS-BONDED Pipe to check severe corrosion or PAVED-INVERT Pipe where erosion is the problem.

For large structures there is ARMCO MULTI-PLATE Pipe or Arches. These are shipped to the site "knocked down" ready for quick field assembly. If headroom is limited, either a plain corrugated PIPE-ARCH or a MULTI-PLATE PIPE-ARCH is just the thing.

Material costs are low because you choose exactly what you need in a wide range of sizes, from 6-inch round pipe to a 24-foot MULTI-PLATE Arch. A small, unskilled crew does the work without special tools or heavy equipment. Labor costs are low.

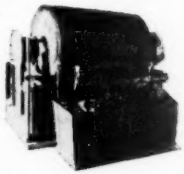
Why not talk over that next sewer problem with the ARMCO Engineer—or write for complete information. Armco Drainage & Metal Products, Inc., 1235 Curtis Street, Middletown, Ohio.

ARMCO SEWERAGE PRODUCTS

ARMCO

Many modern progressive cities have installed or are in the process of installing equipment to give maximum protection to their citizens by dewatering sewage sludge with Eimco Continuous Vacuum, sludge dewatering equipment.

To the engineer, Eimco equipment provides a definite means of figuring the job on a predetermined dewatering basis as weather and other unpredictable features are eliminated.



To the city, Eimco equipment offers a definite saving as the engineer is able to make his digestors or sludge storage tanks smaller when dewatering can proceed at a definite rate. Maintenance should be less on vacuum filters than on sludge beds when, over the years, man hours and materials are considered.

Eimco vacuum filters are engineered especially for each sewage job. The many factors entering into the Sanitary Engineers survey are factors in which we, as manufacturers, are also interested in order to assure a satisfactory filter installation. Many installations including Summer & Winter resorts, industrial plants, plants treating industrial wastes exclusively and other cities where domestic and industrial wastes are combined are all successfully using Eimco equipment — in many cases Eimco equipment working side by side with other equipment is doing a superior job.

Your inquiry is invited.

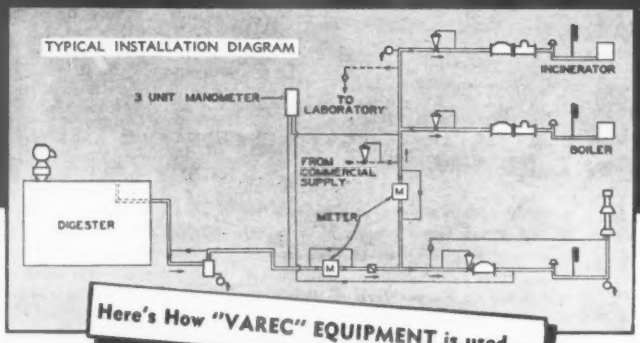
Cities using Eimco sludge dewatering Equipment include: City of East Chicago, Ind.; City of Baltimore, Md.; City of Great Neck, L. I., N. Y.; City of Cranston, R. I.; City of Tonawanda, N. Y.; City of Birmingham, Mich.; City of Enumclaw, Wash.; City of Bolgrove, L. I., N. Y.; City of Piqua, Ohio; City of Anderson, Ind.; City of Wausau, Wis.; City of Stamford, Conn.; and many others.

EIMCO

THE EIMCO CORPORATION

A195

AUTOMATIC WASTE GAS BURNING
WITH
"VAREC" SEWAGE GAS CONTROL EQUIPMENT



Here's How "VAREC" EQUIPMENT is used....

"VAREC" Fig. 58C Pressure Relief and Vacuum Breaker Valve with Flame Arrester—*Relieves excess pressures and vacuum in digesters and protects vessels from outside fires.*

"VAREC" Fig. 230, 232 or 233 Sediment Trap } *keeps lines drained and*
"VAREC" Fig. 245 or 248 Drip Trap } *free from moisture.*

"VAREC" Fig. 211 or 211A Check Valve—*controls direction of gas flow.*

"VAREC" Fig. 51A or 52A Flame Check—*prevents flashback from burner pilot light or laboratory burners.*

"VAREC" Fig. 440 Pressure Relief and Flame Trap Assembly—*permits excess pressure to be wasted through gas burner and prevents flame flashback from burner.*

"VAREC" Fig. 187 or 387 Pressure Reducing Regulator—*controls pressure of gas going to utilization equipment.*

"VAREC" Fig. 450 Flame Trap Assembly—*prevents flame propagation in piping.*

"VAREC" Fig. 70 Explosion Relief Valve—*relieves sudden surges in pressure from explosion or momentary plant fluctuations.*

"VAREC" Fig. 215, 215A, 216 or 216A Manometer—*indicates system pressures.*

"VAREC" Fig. 236, 237 or 238 Waste Gas Burner—*efficiently burns all excess gas.*

Write for Catalog S-3

PROVED and APPROVED "Varec"

THE VAPOR RECOVERY SYSTEMS COMPANY
COMPTON, CALIFORNIA, U.S.A.

NEW YORK 30 CHURCH ST · PITTSBURGH 939 GULF BLDG · CHICAGO 122 SO MICHIGAN AVE
TULSA 409 TULOMA BLDG · HOUSTON 821A M.&M. BLDG

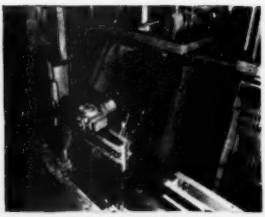
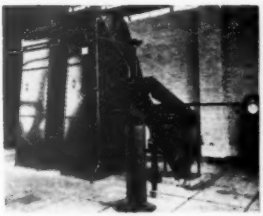
Available from Authorized Sewage Equipment Agents throughout U. S. and Canada

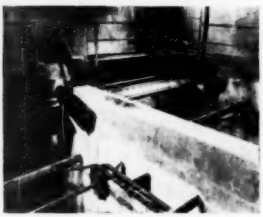
S-7

The treatment of water and sewage by mechanical means has definitely proved most effective and economical — is the accepted practice in practically all modern plants. Jeffrey Sanitation Engineers are Specialists— treat each case in a practical way — are qualified by experience to offer technical information on equipment and plant design. Send for list of Jeffrey-equipped plants now giving day-in and day-out service.

a treat to get right treatment

for instance



The five photos show the application of Jeffrey Screens, Collectors, Scum Removers and Grit Washers in both large and small plants. Also Sludge Elevators, Chemical Feeders, Screenings Grinders and equipment for biofiltration plants. Catalog No. 775-A goes into detail.

JEFFREY ESTABLISHED 1877

SALES OFFICES IN PRINCIPAL CITIES

THE JEFFREY MANUFACTURING COMPANY • 902 NORTH FOURTH STREET, COLUMBUS, OHIO

Storm Drains for Modern Expressways are Built of *CONCRETE PIPE*

THE CALUMET Expressway, a new highway entering Chicago from the south, will be drained by modern, economical concrete pipe. The drawing above shows a typical section.

In the drainage system water is collected at the pavement edges and channeled to catch basins located off both shoulders and under the median strip. From them the water is delivered to a single large-diameter concrete pipe near the center line.

Concrete pipe has been used for storm drains and sewers for more than a century. That experience has demonstrated that concrete pipe has long life and costs little or nothing to maintain. These factors, combined with its moderate first cost, add up to ***low-annual-cost*** drainage.

Concrete pipe has the strength to sustain heavy overburdens. Its smooth interior finish resists abrasion and provides maximum hydraulic capacity.

When planning a storm drainage system—or a sanitary sewer—specify concrete pipe for ***low-annual-cost*** service.

Photos show installation of concrete catch basin and 84-in. concrete pipe on Calumet Expressway. The size of the concrete pipe in this project ranges from 12 in. to 96 in. in diameter.

PORTLAND CEMENT ASSOCIATION

33 W. Grand Avenue • Chicago 10, Illinois

A national organization to improve and extend the uses of portland cement and concrete through scientific research and engineering field work

THE CYLINDRICAL PLUG of an a.c.f. type valve needs no lifting from a tapered seat:

• Quick operation, if needed • A quarter turn—full flow • A quarter turn—full shut-off • Straight-through flow—most desirable • *Round* full pipe area port*—no restriction • No exposed seats when on flow—no abrasion • Lubricated—for long life and corrosion protection.

*Can be supplied in rectangular port with full area.

a.c.f. CYLINDRICAL FULL PIPE AREA LUBRICATED **PLUG VALVES**

Representatives in more than 30 principal cities.

Ideal for sewage operations. Ask for catalog 4-SJ. American Car and Foundry Company, Valve Division, 30 Church St., New York 8, N. Y.

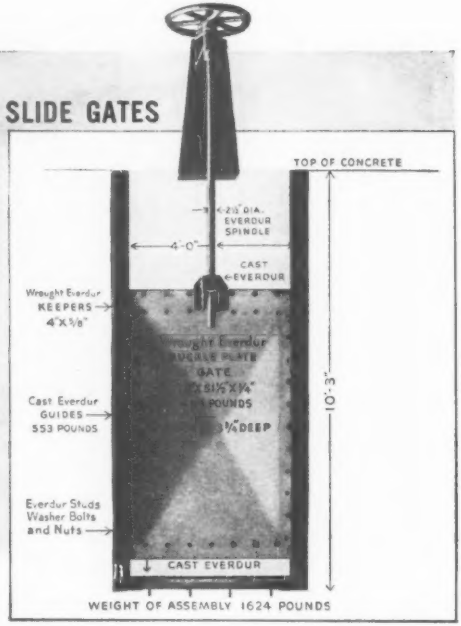
FROM COTTER PINS TO SLIDE GATES

Everdur

STANDS UP

LONGER IN

SEWAGE SERVICE



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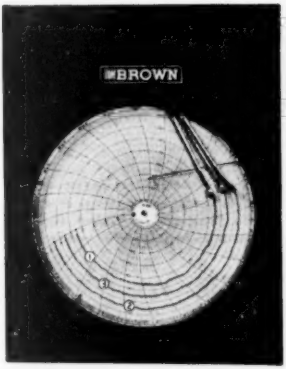

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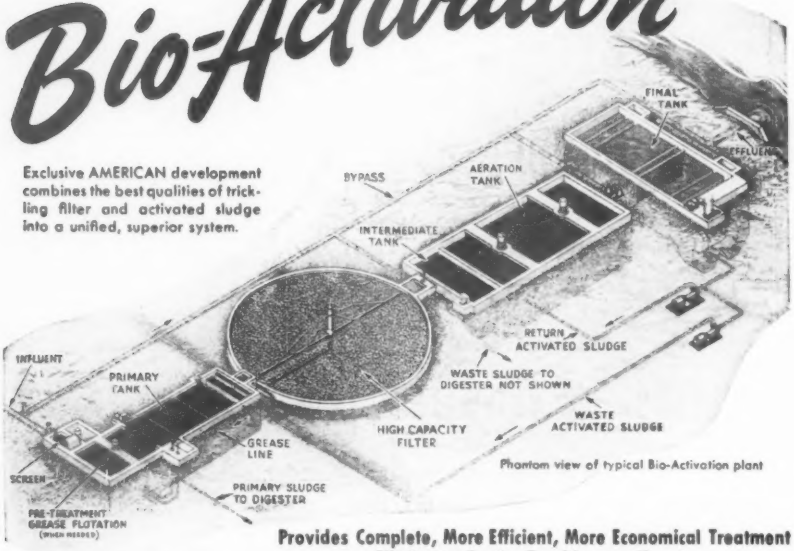

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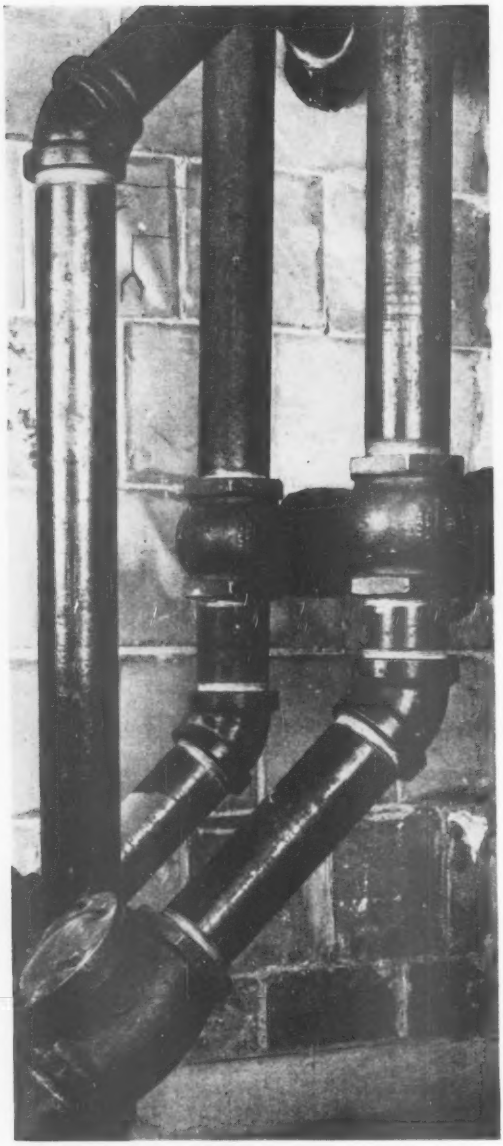

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SEWAGE WORKS JOURNAL

Official Bimonthly Publication — Federation of Sewage Works Associations

Volume XXI | SEPTEMBER, 1949 | Number 5

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W. H. Wisely, *Editor*, 325 Illinois Building, Champaign, Illinois
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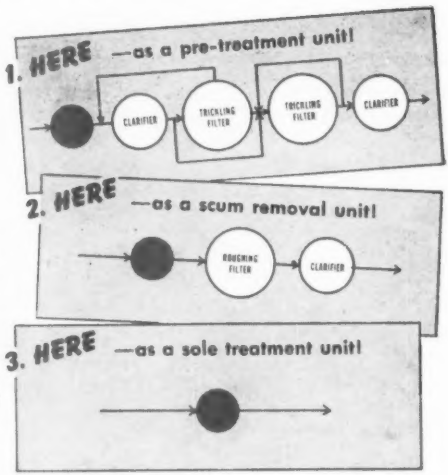

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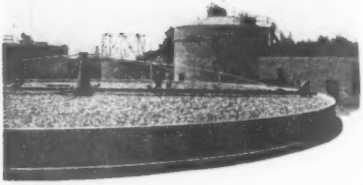

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Sewage Works

SYSTEM OF BIO-PRECIPITATION OF ORGANIC MATTER FROM SEWAGE[1]

By Daniel A. Okun[2]

Associate Engineer, Malcolm Pirnie Engineers, New York, N. Y.

The production of oxygen at low cost by air liquefaction and rectification raised the possibility of its use in the aerobic, biological treatment of sewage. Investigation into this possibility was initiated at the suggestion of Mr. Malcolm Pirnie, who, at the same time, outlined a method of treatment that might employ pure oxygen to good advantage. This method has been termed "bio-precipitation" (1).

The techniques and apparatus developed, together with the use of pure oxygen, provided a means for gaining new insight into factors affecting aerobic treatment of sewage in general, as well as bio-precipitation in particular. It is the purpose of this paper (a) to report and assess the results of some of these investigations and (b) to suggest that bio-precipitation, using tonnage oxygen (about 95 per cent purity), offers the possibility of considerable economies in sewage treatment plant construction.

Laboratory Studies

Inasmuch as the aerobic biological treatment of sewage involves the removal and stabilization of polluting material which is either in colloidal suspension or dissolved, and which cannot be removed efficiently by direct physical means, and as the investigation in hand was concerned with this "secondary" treatment alone, it was decided to feed well-settled sewage, as "raw" sewage influent, to the experimental treatment units.

Sewage was pumped from a combined sewer at about 10 o'clock every morning (the time at which the sew-

TABLE I.—Analyses of Settled Oxford Street Sewage*

Date Sewage Pumped	1/5/1948	1/7/1948
Settleable Solids	0	0
Total Solids	358	300
Fixed	165	138
Volatile	193	162
Suspended Solids	124	103
Fixed	29	23
Volatile	95	80
Dissolved Solids	234	197
Fixed	136	138
Volatile	98	59
Chlorides	45	38
Alkalinity	176	146
Acidity	21	26
Nitrogen		
Ammonia-N	58	16
Organic-N	13	8
Nitrite-N	0	0
Nitrate-N	0	0
B.O.D. (5-day, 20° C.)†	178	152

* These data are averages of two determinations on samples from crocks, taken 16 hours apart, in parts per million.

† B.O.D. averaged 140 p.p.m. for period of experiment; pH averaged 7.2.

[1] Presented at Twenty-first Annual Meeting, Federation of Sewage Works Assns.; Detroit, Mich.; October 18–21, 1948.

[2] The investigations reported in this paper were conducted while the author was Teaching Fellow, Graduate School of Engineering, Harvard University.

age is generally strongest) into a storage tank in the basement of the laboratory. No significant amount of industrial wastes is tributary to the sewer at this point. After settling for 1.5 hours, settled sewage was drawn through a float intake from a point just below the surface and pumped into elevated crocks in the laboratory. Analyses of typical samples of raw (settled) sewage are shown in Table I. The arrangement, together with a schematic diagram of the experimental units, is shown in Figure 1.

Laboratory Bio-Precipitation Units

The flow of influent sewage from the crocks was continuous, and was controlled by a float valve designed to maintain a constant level in the reservoir. From this influent reservoir, the sewage was made to flow down a tapered glass oxygenating tube, countercurrent to the upward movement of oxygen bubbles released at the bottom of the tube. A small pump discharged the oxygenated sewage into the bottom of the precipitation unit, which contained the suspended biological floc. The precipitation tube was constructed of Lucite tubing, 1¾ in. inside diameter and 52½ in. long. The sewage flowed upward through the masses of suspended floc, and the effluent was collected at the top, its discharge being controlled by a second pump.

Oxygen was obtained from standard high-pressure cylinders. A two-stage

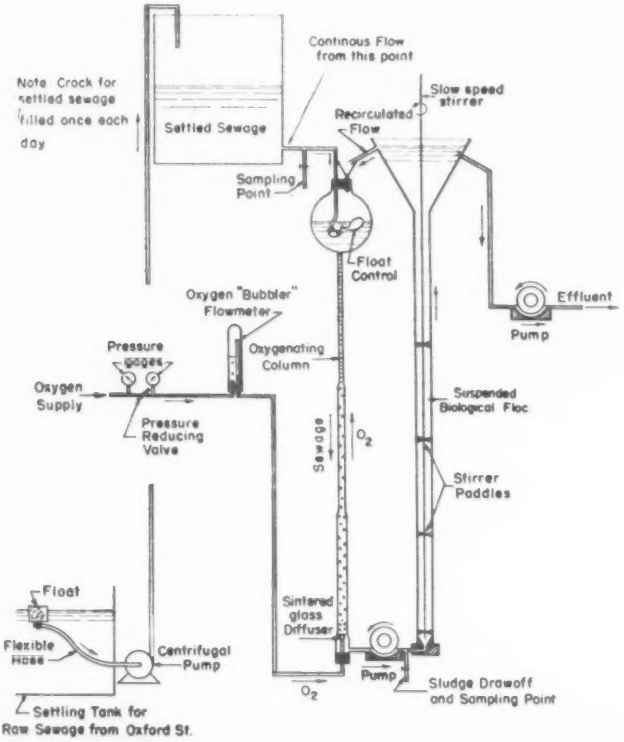


FIGURE 1.—Schematic diagram of experimental laboratory bio-precipitation apparatus.

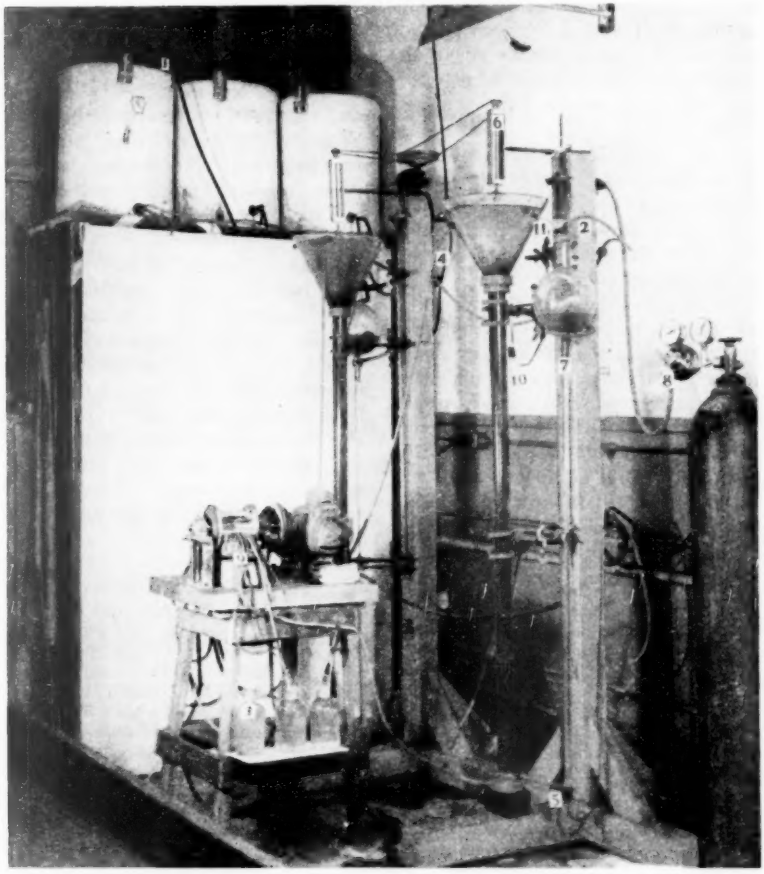


FIGURE 2.—Experimental bio-precipitation units; left-hand unit operated on air, right-hand on oxygen: (1) discharge hose for settled sewage, (2) influent to right-hand unit, (3) sample of settled influent sewage, (4) effluent line to pump, (5) diffuser in oxygenation tube, (6) bearing support for slow stirrer in precipitation unit, (7) oxygenation tube, (8) pressure-reducing valve on oxygen cylinder, (9) pump for both units, (10) oxygen bubbler flow-meter, (11) recirculated flow from precipitation unit to influent reservoir.

pressure-reducing valve maintained a 10- p. s. i. operating pressure behind a 10-mm. fine, sintered glass diffuser, and a bubbler flowmeter was used to measure the rate of flow of oxygen.

At normal sewage temperature in the laboratory (20° C.) and at atmospheric pressure (plus 5 ft. of hydrostatic head), the maximum oxygen concentration attainable in the sewage in the oxygenating tube was about 35 p.p.m. Analysis of the data reported by McKee and Fair (2), on the oxygen utilization of activated sludge developed and fed with sewage from the same source as that used for these experiments, revealed that recirculation of effluent would be required to provide

sufficient oxygen for the process. Effluent was recirculated by gravity flow from the surface of the liquor in the precipitation unit to the influent reservoir, where it mixed with the raw sewage.

A more satisfactory flow pattern—one which would probably be adopted in plant scale operation—should provide for withdrawal of the recirculated flow below the surface, thus decreasing the effluent overflow rate.

The cone at the top of the precipitation unit was provided to prevent accidental escape of the floc, or loss associated with excessive upward velocities. The cone served also as an upper "control section" in which extreme changes in the condition of the floc suspensions could be absorbed by virtue of a decrease in upward velocity with increasing cross-sectional area.

A slow-speed stirrer was found to be necessary to limit agglomeration of the floc masses and to avoid short-circuiting of the sewage through "channels" in the floc blanket. The stirrer was constructed from glass rods with four ½-in. blades, set at a 45° angle, spaced at 1-ft. intervals. The stirrer operated at a constant speed of 9 r.p.m., although it would have been preferable to have provided for speed regulation.

Two units were built to permit simultaneous comparative tests to be run. These units are shown in Figure 2. At the time the photograph was taken the left-hand unit was operating with air, but otherwise the units were identical.

For the operation of the two units, four positive flow control devices, including two pumps, were necessary. These were required to deliver from 10 to 300 cc. per minute. The device which was used for this purpose, shown at "9" in Figure 2, was conceived by Dr. S. L. Chang, Assistant Professor of Sanitary Biology in the Department of Sanitary Engineering.

Operating Procedure

The parallel bio-precipitation units were operated continuously with floc formed in the units. The operation and testing of the treatment units were generally based on "runs" made during a 24-hour "treatment day," between noon of one day and noon of the next, in which period the sewage fed to the treatment units was from the same "batch." Each treatment day during which routine samples were collected was assigned a "run number" in chronological order. The letter "L" or "R" after the number indicates that the data apply to the left-hand or right-hand treatment unit. For convenience in analyzing the data, the runs were classified into various series, as shown in Table II. The routine data collected are included in Tables III through VII.

TABLE II.—Classification of Experimental Series

Series	Description	Number Runs
A	Average flow rate, 12.0 cc. per min.	8
A′	As Series A, but operating on air	3
B	Average flow rate, 25.4 cc. per min.	4
C	Average flow rate, 32.6 cc. per min.	3
D	Average flow rate, 40.4 cc. per min.	15
D′	As Series D, but only about 12 hours per treatment day	32
E	Average flow rate, 50.9 cc. per min.	6
F	Average flow rate, 56.4 cc. per min.	2
S	Second stage with Series F as first stage	2
G	Treating sewage with high C/N ratio	2
R	Treating sewage "reinforced" with dextrose nutrient broth	2

Between treatment days, all the floc was generally drawn from the unit for sampling and wasting, the remainder being returned to the unit.

Effluent samples were analyzed as pumped from the units without supplementary sedimentation or filtration.

Analytical Determinations

All determinations were made in accordance with procedures specified in

TABLE III.—Experimental Data: Runs No. 1–No. 9

Run No.	Date	Sewage Flow (c.c./min.)	Flow Factor[1]	B.O.D.			Effl. NO_3-N (p.p.m.)	Biological Floc				Plant D.O. Range (p.p.m.)	Series	Remarks
				Raw (p.p.m.)	Effl. (p.p.m.)	Per Cent Rem.		Wt. (gm.)	Per Cent Vol.	Volume (liters)	Density (ml./gm.)			
1L	10/1	42.8	5.1	95	14.5	84.8	—	9.2	—	1.63	180	7–25	D′	Floc equally to L and R on 9/28
1R		40.8	5.4	95	14.5	84.8	—	9.5	—	1.73	180	8–26	D′	
2L	10/2	41.3	5.2	88	13.0	85.3	—	10.1	45.0	1.50	150	12–28	D′	
2R		39.3	5.5	88	13.8	84.4	—	9.2	45.0	1.73	190	16–32	D′	
3L	10/3	40.8	5.2	74	14.2	81.0	—	12.0	34.0	1.27	100	6–18	D′	Diffuser trouble; Sampled 10/4 A.M.
3R		No run					—	9.9	34.0	1.00	100	0–9	—	
4L	10/5	39.7	5.3	124	25.0	79.9	—	15.0	39.5	0.88	60	4–21	D′	Floc equally to L, R 10/4; Sampled 10/6
4R		39.3	5.4	124	25.4	79.5	—	17.3	39.5	0.96	55	9–26	D′	
5L	10/7	37.8	5.4	89	18.3	79.4	—	16.9	35.0	1.38	80	6–24	D′	Sampled 10/8 A.M.
5R		No run												Oxygenation tube trouble
6L	10/8	36.8	5.5	107	23.7	77.8	—	24.0	34.5	1.79	75	3–26	D	Floc distributed during run, 2:1 to L, R on 10/8
6R		38.0	5.3	107	26.8	74.9	—	12.0	34.5	1.48	120	6–26	D	
	10/10											3–8		Low D.O. accidental
7L	10/10	38.0	5.8	100	23.2	77.8	—	9.8	35.0	2.11	220	7–26	D	Floc 2:1 to L, R on 10/10 and during run, 2:1 to L, R
7R		37.8	6.0	100	25.9	75.3	—	5.4	35.0	1.91	360	6–20	D	
8L	10/11	38.8	5.8	169	21.8	87.2	—	10.3	38.0	2.30	220	9–26	D′	
8R		38.7	5.8	169	26.6	84.4	—	6.3	38.0	2.30	370	2–16	D′	
9L	10/12	38.8	5.8	181	14.5	92.1	—	11.4	41.5	2.51	220	4–24	D′	
9R		41.5	5.1	181	25.4	86.0	—	6.6	41.0	2.91	440	Tr-13	D′	

[1] Ratio of flow in precipitation unit to sewage flow treated.

TABLE IV.—Experimental Data: Runs No. 10–No. 19

Run No.	Date	Sewage Flow (c.c./min.)	Flow Factor[1]	B.O.D.			Effl. NO$_3$-N (p.p.m.)	Biological Floc				Plant D.O. Range (p.p.m.)	Series	Remarks
				Raw (p.p.m.)	Effl. (p.p.m.)	Per Cent Rem.		Wt. (gm.)	Per Cent Vol.	Volume (liters)	Density (ml./gm.)			
10L	10/13	48.5	5.4	138	26.4	81.0	—	8.5	48.0	2.69	320	16–29	D′	Floc 2:1 to L, R on 10/13;
10R		44.5	4.4	138	25.6	81.6	—	5.6	47.5	2.51	450	14–33	D′	Sampled 10/14 A.M.
11L	10/14	44.5	5.7	131	29.9	77.3	—	6.4	46.5	—	—	16–34	D′	Stopped oper. on 10/14
11R		43.5	5.0	119	25.7	78.5	—	5.4	44.0	1.38	260	13–32	D	
12L	10/15	44.3	—	—	—	—	—	—	—	—	—	—	—	Started L fresh on 10/14
12R		45.0	4.7	122	35.2	71.3	—	8.8	39.0	0.69	80	9–29	D′	
13L	10/16	43.0	5.9	110	35.7	67.7	—	3.2	51.0	0.46	140	15–30	D′	New floc as of 10/14
13R		45.0	5.7	110	15.7	85.8	—	10.9	39.5	0.71	65	13–32	D′	Original floc
14L	10/17	40.8	5.9	132	23.9	82.0	—	4.0	51.0	0.54	140	6–22	D	Floc as of 10/14 Sampled
14R		43.8	5.8	132	25.5	80.7	—	12.1	39.5	0.69	60	4–19	D	Original floc 10/18 A.M.
15L	10/18	42.3	3.7	75	14.2	81.1	—	5.9	52.0	0.75	120	8–25	D′	As Run No. 14L Sampled
15R		37.7	4.6	75	16.6	78.0	—	9.7	43.5	0.66	70	2–21	D′	As Run No. 14R 10/19 A.M.
16L	10/19	40.2	6.2	120	15.2	87.3	0.7	6.8	53.0	1.12	160	8–29	D	As Run No. 14L
16R		42.2	5.2	120	23.8	80.2	4.0	11.0	47.0	0.93	85	7–29	D	As Run No. 14R
17L	10/21	42.5	5.6	111	31.1	72.0	—	9.0	56.0	—	—	5–22	D′	As Run No. 14L Sampled
17R		43.5	4.8	111	14.2	87.0	—	13.6	53.5	—	—	5–27	D′	As Run No. 14R 10/22 A.M.
18L	10/22	40.8	5.6	144	35.7	75.2	—	9.7	57.0	2.00	210	Tr-24	D	As Run No. 14L
18R		40.6	4.9	144	14.1	90.3	—	14.5	55.0	2.00	140	1–31	D	As Run No. 14R
19L	10/23	42.8	5.0	147	28.9	80.3	—	9.2	61.0	1.84	200	6–28	D′	As Run No. 14L Sampled
19R		43.5	4.7	147	21.6	85.5		13.4	59.5	1.84	140	8–32	D′	As Run No. 14R 10/24 A.M.

[1] Ratio of flow in precipitation unit to sewage flow treated.

TABLE V.—Experimental Data: Runs No. 20–No. 25

Run No.	Date	Sewage Flow (c.c./min.)	Flow Factor[1]	B.O.D.			Eff. NO_2-N (p.p.m.)	Biological Floc				Plant D.O. Range (p.p.m.)	Series	Remarks
				Raw (p.p.m.)	Eff. (p.p.m.)	Per Cent Rem.		Wt. (gm.)	Per Cent Vol.	Volume (liters)	Density (ml./gm.)			
20L	10/24	46.0	3.2	145	37.7	74.1	—	10.0	63.5	1.27	130	4–33	D′	Orig. floc. 2:1 to L, R on 10/24; Sampled 10/25 A.M.
20R		41.7	6.5	145	45.6	68.5	—	5.2	64.0	0.85	160	18–34	D′	
21L	10/25	43.2	4.8	144	18.1	87.5	5.7	11.8	66.0	1.92	160	7–31	D′	Floc 2:1 to L, R on 10/24; Sampled 10/26 A.M.
21R		41.4	5.9	144	28.8	80.0	4.0	6.6	68.0	1.38	210	15–34	D′	
22L	10/26	41.5	6.0	119	14.3	88.0	—	11.2	67.0	2.10	190	6–26	D′	Sampled 10/27 A.M.
22R		40.0	6.2	119	18.2	84.6	—	6.2	70.0	1.84	300	12–31	D′	
23L	10/28	42.5	3.5	210	25.4	87.9	+	9.1	72.0	1.69	180	Tr–25	D′	Accident in L on 10/29. Floc 1:3 to L, R on 10/28
23R		41.8	5.2	173	18.5	89.2	+	6.6	75.0	1.77	280	6–31	D	
24L	10/29	40.2	4.8	137	21.8	84.2	1.1	2.6	74.0	0.59	230	11–31	D	
24R		40.9	5.6	137	15.8	88.5	2.5	6.0	76.5	1.94	320	15–33	D	
25L	10/31	38.2	5.6	215	23.4	89.1	—	4.6	78.0	0.92	200	10–32	D′	
25R		41.1	5.6	190	21.9	88.5	—	7.5	78.0	2.02	270	6–33	D	
25L	11/1	32.3	6.6	148	52.2	64.7	—	—	—	—	—	—	—	All floc removed 10/31

[1] Ratio of flow in precipitation unit to sewage flow treated.

TABLE VI.—Experimental Data: Runs No. 26–No. 34

Run No.	Date	Sewage Flow (c.c./min.)	Flow Factor[1]	B.O.D.			Effl. NO_2-N (p.p.m.)	Biological Floc				Plant D.O. Range (p.p.m.)	Oxygen Utiliz. (p.p.m.)	Series	Remarks
				Raw (p.p.m.)	Effl. (p.p.m.)	Per Cent Rem.		Wt. (gm.)	Per Cent Vol.	Volume (liters)	Density (ml./gm.)				
26L	11/15	9.4	23.2	105	13.0	87.6	4.2	2.6	68.3	0.56	220	23–27	56–88	A	Floc 1:1 to L, R on 11/13
26R		50.2	4.6	105	26.0	75.3	1.8	5.8	73.9	1.49	260	9–31	48–64	E	
27L	11/17	10.4	22.0	159	13.4	91.5	4.3	3.0	70.0	0.56	190	24–27	50–66	A	
27R		50.4	4.8	159	35.8	77.6	0.4	8.7	77.8	2.27	260	12–36	60–68	E	
28L	11/19	12.6	15.4	131	12.6	90.5	+	4.6	74.2	1.53	330	13–25	57–98	A	Floc 1:1 to L, R on 11/18
28R		53.8	4.0	131	22.5	82.8	—	7.0	78.0	2.15	310	9–29	46–53	E	
29L	11/21	12.5	13.0	129	12.3	90.5	7.2	3.8	74.2	0.98	260	20–25	44–58	A	
29R		50.4	4.0	129	18.4	85.8	—	8.9	79.9	2.27	260	0–34	64–65	E	
30L	11/26	13.0	7.7	138	14.2	89.5	—	5.7	80.0	1.07	190	9–23	—	—	Trouble in L, floc 2:1 to L, R on 11/24
30R		51.8	2.9	138	19.2	86.0	—	6.4	82.4	1.27	200	9–26	48	E	
31L	11/28	11.9	16.8	112	7.4	93.5	+	4.8	78.5	1.54	320	14–22	131	A	
31R		48.8	4.9	112	20.0	82.2	—	7.9	83.0	1.08	140	14–28	70	E	
32L	12/5	11.7	15.2	211	14.6	93.1	Tr.	7.6	79.8	1.87	250	Tr-5	68–72	A′	Air 12/4
32R		12.8	16.0	211	10.8	94.9	3.2	9.8	83.0	1.28	130	12–25	108–198	A	Oxygen 12/2 } Floc 1:1 to L, R on
33L	12/7	12.4	11.3	170	13.6	91.9	0	7.1	79.0	2.02	280	0–5	57	A′	Air
33R		12.4	14.5	170	14.7	91.2	2.2	9.3	83.0	1.17	120	11–21	141	A	Oxygen
34L	12/13	12.6	15.9	177	13.1	92.6	0	6.1	81.0	1.27	210	Tr-4	51	A′	Air
34R		14.2	15.4	177	9.1	94.8	1.0	8.6	83.0	2.00	230	12–20	124	A	Oxygen

[1] Ratio of flow in precipitation unit to sewage flow treated.

TABLE VII.—Experimental Data: Runs No. 35–No. 44

Run No.	Date	Sewage Flow (c.c./min.)	Flow Factor[1]	B.O.D.			Effl. NO_3-N (p.p.m.)	Biological Floc				Plant D.O. Range (p.p.m.)	Oxygen Utiliz. (p.p.m.)	Series	Remarks
				Raw (p.p.m.)	Effl. (p.p.m.)	Per Cent Rem.		Wt. (gm.)	Per Cent Vol.	Volume (liters)	Density (ml./gm.)				
35L	12/31	14.9	12.4	123	31.9	74.2	—	0.7	75.0	0.02	30	1–4	—	—	Air } Plants started fresh on
35R		23.9	5.0	123	36.7	70.1	—	1.0	75.0	0.02	20	30	—	—	Oxy. } 12/30
36L	1/3	15.3	10.9	102	19.3	81.1	0	1.9	78.0	1.80	950	Tr-5	27–52	—	Air
36R		26.0	5.8	102	17.3	83.1	0.1	2.9	79.5	0.71	240	23–31	26–43	B	Oxygen
37L	1/5	13.6	17.0	178	33.8	81.0	0	2.7	81.0	2.00	740	Tr-3	50	—	Air, Plant trouble
37R		23.2	10.0	178	17.3	90.2	0.2	4.5	82.0	2.00	440	24–31	62–68	B	Oxygen
38L	1/7	14.2	10.3	152	57.4	62.2	—	3.0	81.0	0.38	130	0–2	—	—	Air, Plant trouble
38R		24.6	8.6	152	15.5	89.7	0.5	5.2	82.5	2.10	400	19–30	60–86	B	Oxygen
39L	1/16	29.9	3.4	109	12.2	88.8	0.9	4.7	81.0	2.90	620	14–34	67	G	High C/N Sew. } Floc 1:1 on
39R		32.0	3.6	128	16.8	87.0	2.0	4.8	81.5	1.25	260	8–28	61–71	C	Normal Sew. } 1/15
40L	1/19	27.6	6.5	123	19.4	84.1	2.6	5.6	83.0	2.00	360	22–34	70–82	B	Normal Sew. } Floc 1:1 on
40R		31.4	5.6	160	18.3	88.5	1.4	6.8	82.5	2.40	360	11–28	68–90	G	High C/N Sew. } 1/17
41L	1/24	29.6	7.0	173	19.8	88.5	2.6	7.1	83.0	2.37	330	18–32	82–85	R	Reinf. Sew. } Floc 1:1 on
41R		32.8	5.8	131	15.2	88.2	3.9	6.3	82.0	2.03	320	16–30	68–81	C	Normal Sew. } 1/20
42L	1/27	36.1	4.6	194	23.6	87.8	Tr.	8.5	85.5	2.15	250	4–26	96–98	R	Reinforced Sewage
42R		33.1	7.4	116	9.1	92.0	3.4	5.7	82.0	2.37	420	21–34	81–82	C	Normal Sewage
43L	2/2	56.7	3.9	133	22.1	83.4	0.6	7.5	83.6	2.90	390	13–33	67–76	F	1st Stage } Floc 1:1 on 1/29
43R		48.2	5.2		10.0	92.5	3.4	3.4	79.0	1.46	430	25–31	28–31	S	2nd Stage }
44L	2/3	56.2	4.0	127	18.0	85.9	0.8	6.5	83.7	2.12	330	14–32	67–71	F	1st Stage
44R		48.0	5.3		10.3	91.8	3.4	3.7	79.0	1.36	370	26–31	20–25	S	2nd Stage

[1] Ratio of flow in precipitation unit to sewage flow treated.

"Standard Methods" (3), except as noted below:

Determinations of dissolved oxygen were made by the Winkler test. Because of the high dissolved oxygen concentrations, the alkaline-iodide reagent recommended by Pomeroy and Kirschman (4) was used. Interference due to nitrites was eliminated by the addition of sodium azide solution directly to the alkaline-iodide solution as directed in "Standard Methods."

Solids determinations of biological floc were run as total solids, including dissolved solids in the liquor. Inasmuch as the solids were concentrated to one liter prior to sampling, the error involved was less than 5 per cent. The saving in time effected by the determination of total and total volatile solids over that required for total and volatile suspended solids was considerable.

Factors Affecting Biological Sewage Treatment Units

The transfer of organic pollute from sewage to zoogleal growths in biological sewage treatment is primarily a surface phenomenon. The degree of sewage treatment effected is, therefore, a function of the area of "interface." Although there is no direct method for measuring this area, the weight of solid material in the system may be used as a measure of the extent of contact surface. The removal of the pollute from the sewage by active floc is also dependent upon the time of contact, which evaluates the opportunity for contact between the sewage and the floc particles. A measure of contact time, albeit not an entirely satisfactory one, is the detention period of the sewage within the volume occupied by the floc. A third inherent factor affecting the degree of treatment is the organic load impressed upon the treatment system.

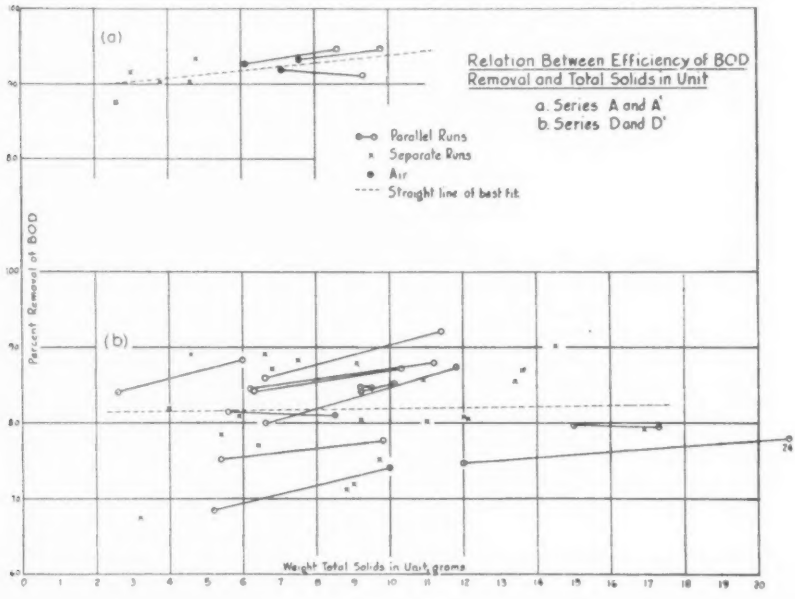


FIGURE 3.

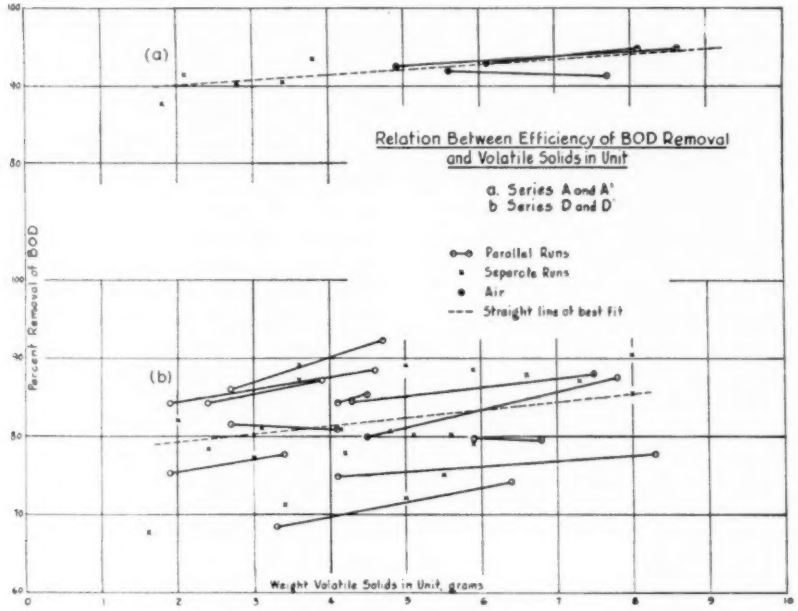


FIGURE 4.

which is conveniently expressed in terms of weight of B.O.D. applied per day.

Effect of Weight of Floc on B.O.D. Removal

To investigate the relationship between weight of biological floc and efficiency of purification, comparative runs were made simultaneously at equal rates of sewage flow by mixing the floc from the two plants and apportioning it between the two initially in the ratio of 2 : 1 or 3 : 1 (Runs 6–10 and 20–24). Efficiency of B.O.D. removal is plotted against total solids in Figure 3, and against volatile solids in Figure 4, wherein the parallel runs are shown by connected points. The unconnected points were obtained during tests when other factors were being investigated and are included because the rate of sewage flow was the same.

As was to be expected, the parallel runs reveal that higher solids concentrations in the unit resulted in increased B.O.D. removal.

Study of the slopes of the lines connecting points for the comparative runs indicates little difference between the use of total solids as against volatile solids in establishing the effect of changing floc weight. It must be realized, however, that, in each comparative run, the percentage of volatile solids was practically the same in the two units.

On the other hand, the straight line of best fit for all the runs of the series, during which the volatile content varied from 34 to 78 per cent, is almost horizontal (indicating no correlation, $r = 0.03 \pm 0.10$) when efficiency is plotted against total solids in Figure 3b. There is, however, a correlation ($r = 0.30 \pm 0.09$) between percentage

B.O.D. removal and volatile solids as indicated in Figure 4b by the straight line of best fit for all the runs.

It may be concluded, therefore, that efficiency of B.O.D. removal is a function of the weight of volatile solids in the system rather than total solids. Where there is little variation in the volatile content, the use of total solids as the parameter is valid. This is illustrated by the results from Series A, shown in Figures 3a and 4a. The coefficient of correlation between B.O.D. removal and total solids ($r = 0.60 \pm 0.15$) is practically the same as that between B.O.D. removal and volatile solids. The volatile content in this series varied only from 68.3 to 83 per cent.

It should be noted that although Series A yielded a higher coefficient of correlation than Series D and D′, it is not as significant. If no correlation existed in either case, as great or greater coefficient could have resulted by chance 6 per cent of the time for Series A, and only 2.5 per cent of the time for Series D and D′.

Comparison with Activated Sludge Process

It has long been recognized that the efficiency of the activated sludge process can be improved by increasing the solids concentration in the aeration tanks. Ardern and Lockett (6), in their original paper, showed that increasing quantities of activated sludge resulted in greater purification. Harris, Cockburn, and Anderson (7), in 1926, recognized the significance of the quantity of biologically active sludge, and proposed a coefficient of interfacial contact as a measure of operating control. In the operation of activated sludge plants there is a practical limit to the amount of sludge that can be carried satisfactorily. Freese (8) has stated that ". . . a large proportion of sludge probably retards the oxygenation of the sewage proper because of the relatively greater oxygen requirements of the sludge." In addition, the efficiency of aeration itself is reduced when there is a high solids concentration in aeration tanks. To achieve greater efficiency by carrying more solids in activated sludge plants, therefore, it becomes necessary to increase the aeration tank capacity. In existing plants, by contrast, the tendency has been to operate with lower and lower solids concentrations (9) in order to reduce the cost of air compression.

Aeration tanks in the activated sludge process cannot make as complete use of the tank capacity by filling it with solids as can a bio-precipitation unit. In the latter, high solids concentrations in no wise interfere with oxygenation inasmuch as the precipitation unit serves to transfer pollute from the sewage to the biological floc, while addition of oxygen to the system is accomplished ahead of the precipitation unit.

In Series A of these studies, the average floc density was 225 ml. per gram (4,500 p.p.m.), twice the concentration generally maintained in standard aeration tanks. In some instances the concentration exceeded 10,000 p.p.m. with no deleterious effects. Higher concentrations could be attained by controlling the speed of stirring. It may be concluded, therefore, that for equivalent sewage purification, a precipitation unit for a bio-precipitation plant might be considerably smaller than the aeration tank for a standard activated sludge plant. And, of course, final sedimentation tanks are not required in bio-precipitation.

Effect of Volume of Floc on B.O.D. Removal

The time of contact, or detention time, of the sewage in the volume occupied by the biological floc is a second factor that influences B.O.D. removal. In the experimental units, for any

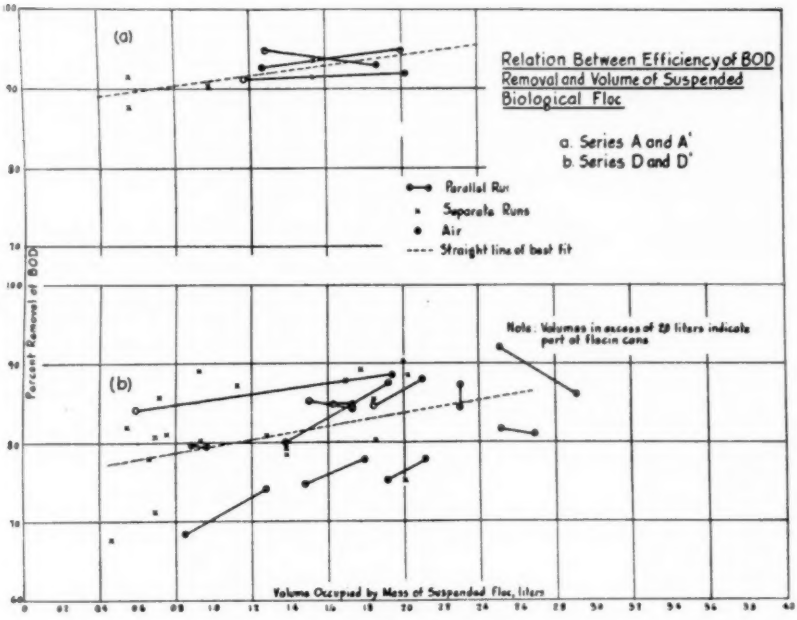

(a)
(b)
Relation Between Efficiency of BOD Removal and Volume of Suspended Biological Floc
a. Series A and A'
b. Series D and D'
Parallel Run
Separate Runs
Air
Straight line of best fit
Note: Volumes in excess of 2.0 liters indicate part of floc in cone
Percent Removal of BOD
Volume Occupied by Mass of Suspended Floc, liters

FIGURE 5.

given sewage flow, the contact time was determined by the volume of the suspended biological floc in the unit. For example, for Series D and D', with an average sewage flow of about 40 c.c. per min., the detention time was 50 min. when the floc occupied a volume of 2.0 liters in the precipitation unit.

B.O.D. removals are plotted against volumes of floc in Figure 5. Pairs of points are joined, as before, to indicate parallel runs. (Inasmuch as the volume in the cylindrical tube of the precipitation unit was 2.0 liters, volumes in excess are not considered reliable because the volume of floc in the cone could not be determined accurately.) As expected, greater volumes of the floc resulted in higher efficiency of B.O.D. removal. The coefficient of correlation ($r = 0.43 \pm 0.09$) was slightly greater than that found with volatile solids, but not significantly so.

Comparison with Activated Sludge Process

The volume of floc is a measure of the requisite size of unit for bio-precipitation treatment, not including the freeboard above the floc blanket necessary to prevent escape of solids into effluent collectors. Comparison of this volume with that of aeration tanks in the activated sludge process will indicate the savings that may be expected by using bio-precipitation as a method of sewage treatment.

A common parameter on which to base the efficiency of activated sludge aeration tanks is the B.O.D. loading per day per 1,000 cu. ft. of aeration capacity. This has the advantage over the use of "detention period" in that it is not affected by differences in the rate of sludge return.

Greeley (10), in an analysis of high-rate activated sludge plants in 1943,

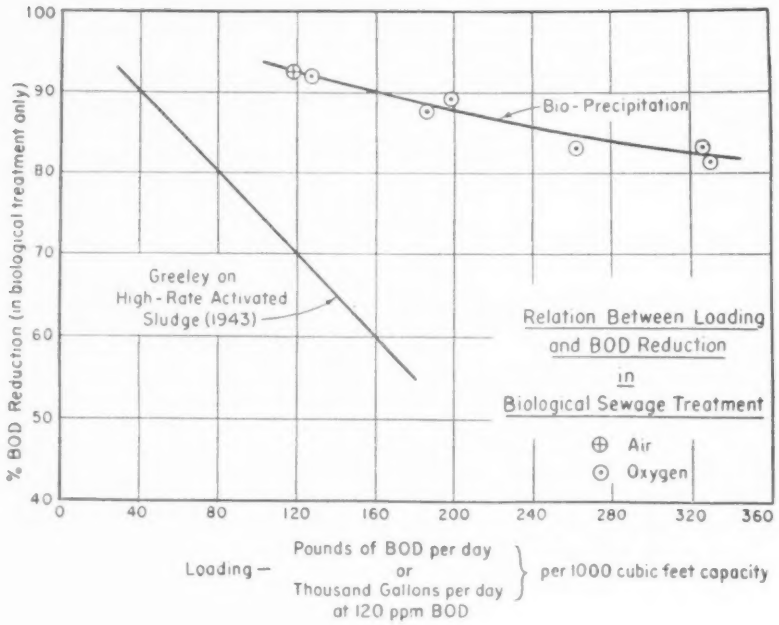


FIGURE 6.

drew a curve, which is reproduced in Figure 6, for purifications obtained with different loadings of aeration tanks. Operating results from conventional municipal activated sludge plants, reported in the NRC report (5), showed an average B.O.D. removal of about 92 per cent for a loading of 21 lb. B.O.D. per day per 1,000 cu. ft. of aeration tank. This value falls near Greeley's line.

The data collected in the bio-precipitation studies are also plotted in Figure 6. Within the range of 85 to 93 per cent of B.O.D. removal, the precipitation units were loaded four times more heavily than the activated sludge aeration tanks for the same degree of treatment, indicating about 75 per cent saving in tank volume, without considering savings in the final sedimentation tanks. At purification values lower than 85 per cent, which may be designated as intermediate treatment, the advantage of bio-precipitation appears to be even greater. This saving in tank volume may be attributed, in part, to the aforementioned fact that a greater weight of floc can be carried per unit volume in the precipitation unit than in conventional aeration tanks.

Effect of Applied Loading on B.O.D. Removal

In comparing the removal of B.O.D. attained under different loadings of the experimental bio-precipitation units (accomplished by varying the rate of flow of raw sewage to the plant), it was found that, as was to be expected, efficiency of treatment decreased with increased loading (Figure 7).

It is recognized that, at the lower loading, the relatively high rates of recirculation dictated by the necessity for suspending the sludge may have been partly responsible for the in-

creased efficiency. No attempt was made to assess the significance of recirculation, and work pointed in this direction is much needed. However, recirculation in bio-precipitation, although similar, is potentially much cheaper than recirculation in high-rate filters because no loss in hydrostatic head is involved.

Evaluation of Bio-Precipitation Performance

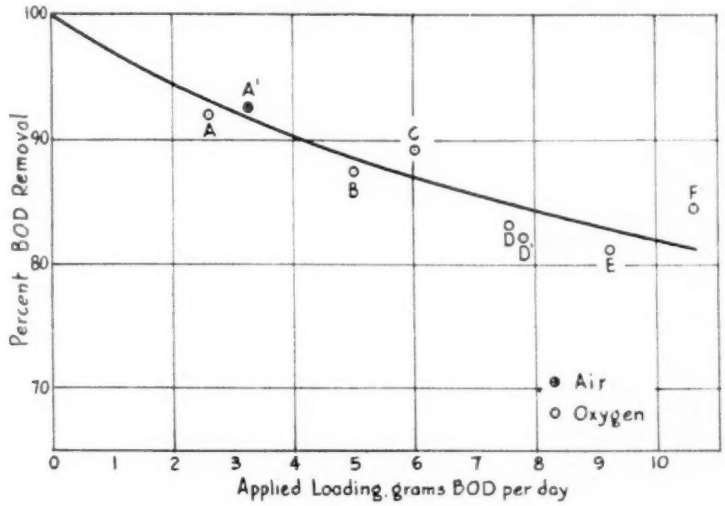
It has been shown that efficiency of B.O.D. removal in bio-precipitation is related directly to the weight of volatile solids in the unit and the contact time, and inversely to the applied organic loading. These factors were assembled into a loading parameter similar to that suggested by Fair (5): weight of B.O.D. applied per day per unit weight of volatile solids per hour of contact time. The data for all the runs are plotted in Figure 8. A reasonably satisfactory curve, in a form suggested by Thomas (5), was fitted to the data. The fitted curve has the equation

$$\text{B.O.D. Removal } (\%) = \frac{100}{1+0.14X^{0.38}}$$

where X = weight of B.O.D. applied per day per unit weight of volatile solids per hour contact. (The contact time—volume of floc in the precipitation unit divided by the rate of flow of raw sewage—varied from about 0.5 hours for the highest loadings to about 2 hours for the lowest loadings used during these experiments.)

Comparison with Activated Sludge Process

The NRC report (5) contains a curve for conventional municipal acti-



Relation Between Efficiency of BOD Removal and Loading Applied to Bio-Precipitation Units

(Letters indicate Series)

FIGURE 7.

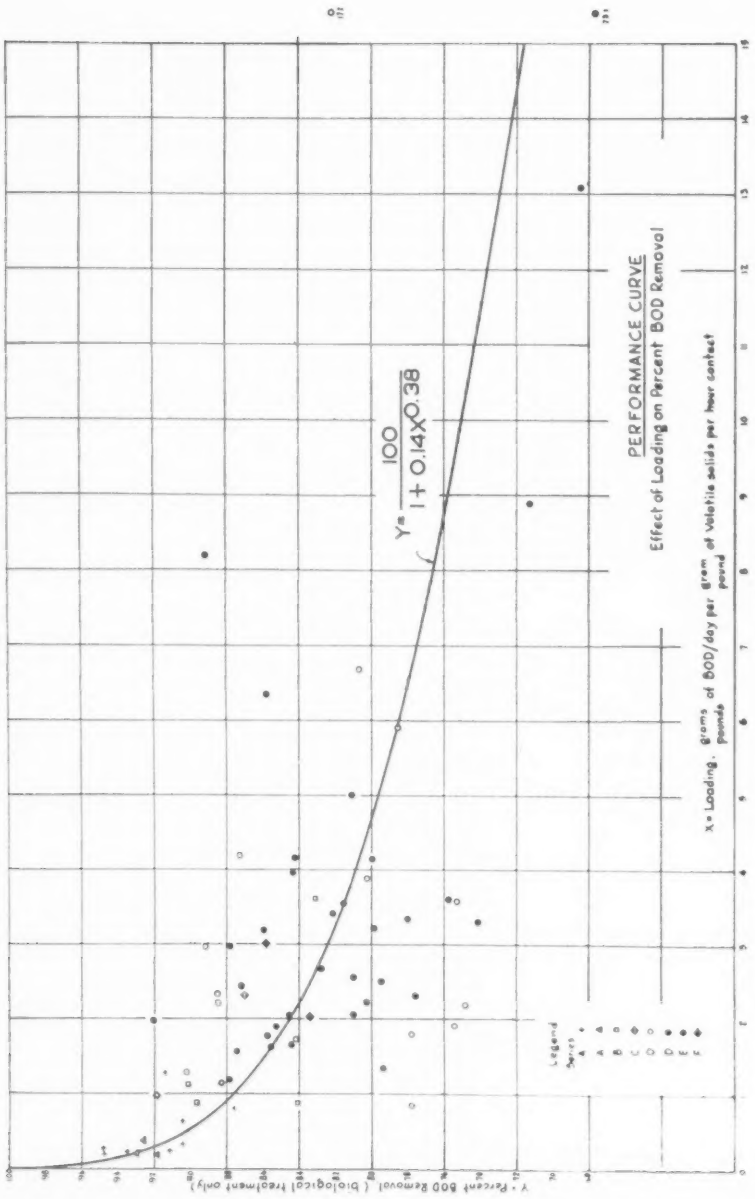

PERFORMANCE CURVE
Effect of Loading on Percent BOD Removal
$Y = \frac{100}{1 + 0.14X^{0.38}}$
X = Loading, grams of BOD/day per gram of volatile solids per hour contact
pounds pound
Y = Percent BOD Removal (Biological treatment only)
Legend
Series
A
B
C
D
E

FIGURE 8.

vated sludge plants similar to that in Figure 8, except that it is based on total suspended solids. By adjusting this curve for a volatile content of 80 per cent, it is found that a B.O.D. removal of 92 per cent would be obtained at a loading of 54 lb. B.O.D. per day per 1,000 lb. of volatile solids per hour of aeration in activated sludge treatment, as against a loading of 300 lb. B.O.D. on the same basis for bio-precipitation, read from Figure 8. At 90 per cent B.O.D. reduction, the relative loadings are 85 lb. for activated sludge treatment and 550 lb. for bio-precipitation. On this basis, therefore, a precipitation unit might be loaded more than five times as heavily as an activated sludge aeration tank.

Effect of Temperature

Biological activity has been shown to follow the van't Hoff-Arrhenius relation within restricted temperature limits. Based on data obtained by Sawyer and Rohlich (12), the Q_{10} (ratio in the rates of reaction produced by 10° C. differences in temperature) for oxygen utilization of activated sludge was found to be about 1.9 at 20° C. This is of the same order of magnitude as the Q_{10} for the anaerobic digestion of sludge, for biochemical oxygen demand, and for the respiration of lake bacteria.

Insofar as the removal of B.O.D. from sewage by activated sludge is concerned, however, the effect of temperature has been shown to be much less marked. Viehl (13) has stated, on the basis of B.O.D. removals, that the rate of carbonaceous oxidation is only slightly affected, if at all, by temperature changes between 8° and 35° C. while the rate of nitrogenous oxidation is greatly affected, being increased two or three times for an increase of 10° C. Sawyer (14) concluded from B.O.D. removal experiments at 10° C. and 20° C., that, with 1,600 p.p.m. of suspended solids or more, the efficiency of treatment was the same at both temperatures.

It may be concluded, therefore, that the better loading characteristics of bio-precipitation, as contrasted with activated sludge treatment, are not attributable to the fact that the average sewage temperature in the laboratory was 22° C., about 7° C. higher than average outdoor sewage temperature.

Effect of Loading on Biological Floc

To study the effect of loading on the biological floc, the two units were operated in parallel on the same raw sewage, with different rates of sewage flow (Runs 26–31). Variations in the rate of growth of floc and its volatile content are shown in the solids log, Figure 9. The average rate of floc formation was 1.9 grams of solids per day for the higher loading, as against 0.4 grams per day for the lower loading. The relative gains in floc weight were in the ratio of 4.8 : 1, while the corresponding rates of sewage flow were in the ratio of 4.2 : 1. Thus, the rate of growth of biological floc per unit volume of applied sewage was greater at higher loadings, despite the fact that a lesser portion of pollute was precipitated from the sewage. Inasmuch as the volatile content of the floc increased at the high loadings, as shown in Figure 9, it is concluded that a greater degree of oxidation of adsorbed organic matter occurs at lower loading.

Similar phenomena have been reported for activated sludge by Ruchhoft and Smith (15) and Heukelekian (16).

Nitrification and Blanket Rising

Consistently greater nitrification, as well as higher B.O.D. removal, took place at the lower loading. It was observed that, on wasting some of the sludge from the two experimental units into beakers, the nitrifying sludge from the unit operated at lower loading rose, within one hour, in an agglom-

erated mass to the top of the beaker. This phenomenon, termed "blanket rising," which has been observed in the final sedimentation tanks of activated sludge plants, has been attributed to the buoyancy imparted to the solids by bubbles of nitrogen gas released from the sludge because of denitrification in the absence of oxygen in the sludge in the final tanks. The system of oxygenation incorporated into bio-precipitation units does not permit "blanket rising" of the floc material to occur.

Loading and Microscopic Life

Differences in loading did not result in marked differences in the microscopic population of the sludge flocs, except that the number and activity of the protozoa were found to be greater at higher loading (Figure 10). Extremely high loading (Series E equivalent to 30 min. of detention in the aeration tanks of activated sludge plants) with high solids concentrations, did not result in deterioration of the biological floc.

Experience has shown that so short

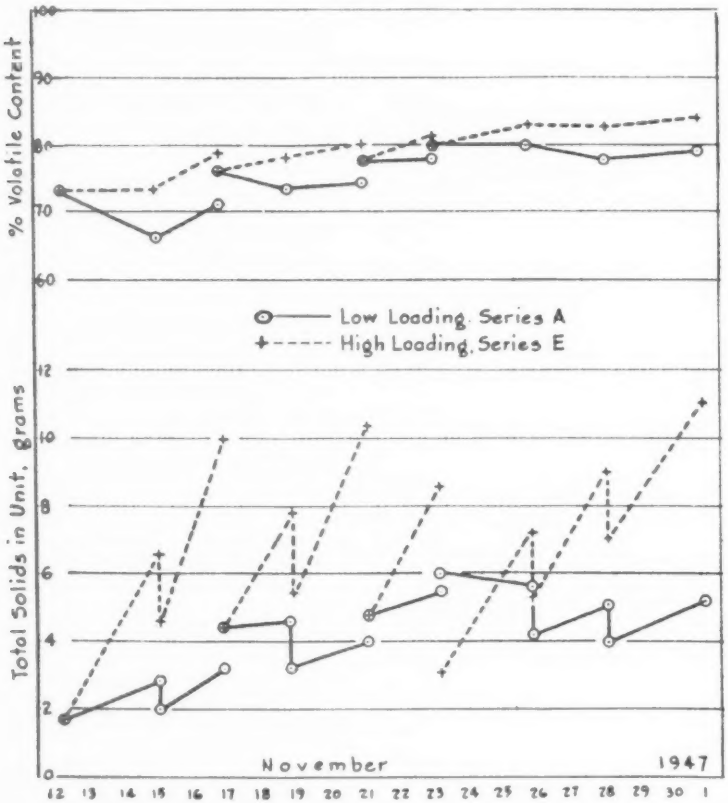


FIGURE 9.—Solids log, showing effect of loading on floc growth. Ratio of loading of Series E to Series A is 4.2 to 1.

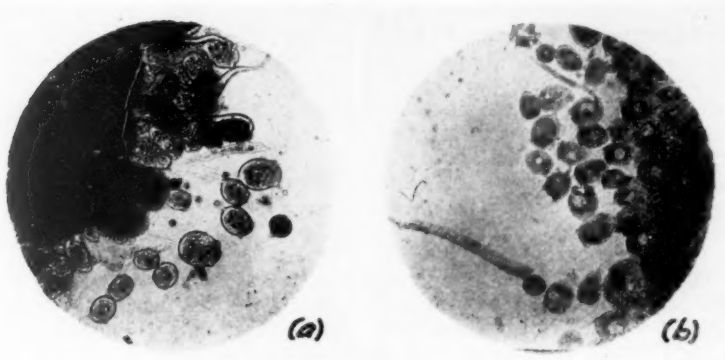


FIGURE 10.—Effect of loading on biological floc: (a) low loading, Series A, (b) high loading, Series E [50 ×].

an aeration period, with high solids concentration, almost inevitably leads to difficulty in the activated sludge process, because sufficient time for aeration is not available to supply the required oxygen to the micro-organisms, and because there is accelerated deterioration of the high oxygen-demand sludge in the final tank.

By pre-oxygenating the influent liquor, the higher oxygen requirements of the process coincident with higher loadings can be met without increasing the capacity of the precipitation unit. By *continuous* provision of oxygen for the micro-organisms, conditions of overloading and deterioration of the biological floc are avoided.

Influence of Oxygen Concentration

Preliminary fill-and-draw experiments were run prior to the construction of the bio-precipitation apparatus to ascertain whether the microbial life associated with activated sludge is benefited or deleteriously affected by the high oxygen concentrations resulting from the use of pure oxygen. An atmosphere of oxygen was maintained in one jar while air was fed to another.

The degree of treatment attained by the use of pure oxygen was found to be very slightly, but consistently, better than with air. Nitrification was not inhibited at the oxygen concentrations (about 33 p.p.m.) maintained in the oxygen-fed unit. The so-called sewage fungus, *Sphaerotilus*, did not develop in the oxygen-fed sludge, although it was found occasionally in the air-fed sludge. Many of the protozoa reported for normal activated sludge were found in the oxygen-supported sludge. This sludge was easier to filter, had a lower sludge index (Mohlman), and was less subject to deterioration than the sludge developed in air.

Oxygen Concentration in Bio-Precipitation

Operation of the experimental bio-precipitation units at low loadings, with consequent lower oxygen requirements, suggested the possibility of using air for oxygenation. Accordingly, the units were run in parallel with one on air and the other on oxygen (Runs 32–34). The dissolved oxygen concentration in the unit operated with air ranged from 5 p.p.m. at the bottom of the unit to zero at the top, while in the oxygen fed unit, the D.O. ranged from 25 to 11 p.p.m.

The results of the air tests (Series A′) are shown in Figures 6, 7 and 8, with the parallel runs against oxygen

indicated in Figures 3a, 4a and 5a. It is evident that no detriment to B.O.D. removal resulted from the use of air per se. It was found, however, that the air-fed unit produced an effluent with no nitrites or nitrates, while the oxygen-fed unit produced a well-nitrified effluent. When using air, even if the floc should be nitrifying, the oxidized nitrogen compounds formed in the lower part of the precipitation unit would tend to be reduced in the upper part where the dissolved oxygen is absent or present in only low concentrations. It is interesting to note that the onset of the second (nitrification) stage was observed to occur on about the fourth day in incubated effluent B.O.D. samples from both units.

Effect of D.O. on Microscopic Life

Six days after initiating parallel operation with air versus oxygen, using the same sludge initially, the floc sustained by air began to show the first marked difference from that maintained at high oxygen concentrations. The former became green-black, and developed considerable growth of *Sphaerotilus*. The oxygen-fed floc was red-brown, and contained very little *Sphaerotilus*. Many protozoa were present in both flocs but they were more active in the oxygen-fed unit.

During the next three days, the differences became more pronounced. In the unit fed with air extensive filaments of *Sphaerotilus* dominated the flocs. Fewer *Vorticella* were present and strands of *Beggiatoa* began to make their appearance. The total number of protozoa was much reduced. It should be noted, however, that during this period the treatment efficiency remained unaffected. Meanwhile, floc in the unit operating with oxygen remained normal. *Sphaerotilus* was almost absent from these flocs, and protozoa were numerous and active. Photomicrographs for comparison of the two sludges are shown in Figure 11.

The air-fed sludge was more difficult to control in the precipitation unit than was the oxygen-fed sludge, and the entire air treatment was quite sensitive.

The only recognizable factor that could have been responsible for the change in the character of the air-supported floc was the lowering of the oxygen concentration consequent to using air. To establish clearly whether this factor was responsible for the abundant growth of *Sphaerotilus*, a

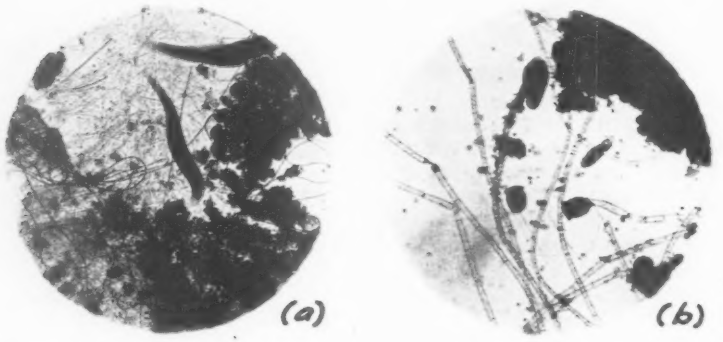


FIGURE 11.—Effect on biological floc of using air as compared with oxygen: (a) air, (b) oxygen [50 ×].

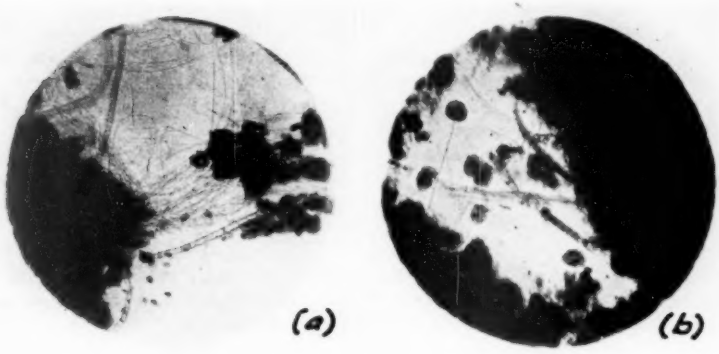


FIGURE 12.—Effect on biological floc using air as compared with oxygen (four days after changing floc): (a) from oxygen to air, (b) from air to oxygen [50 ×].

filamentous organism closely associated with bulking, the sludges in the units were switched.

After four days on air, the sludge previously supported with oxygen had developed extensive growths of *Sphaerotilus* and lost many protozoa. On being supported at high-oxygen concentrations, the floc that had been completely dominated by *Sphaerotilus* was almost entirely cleared of this higher bacterium, and protozoan activity increased considerably. These changes are evident in the photomicrographs in Figure 12.

D.O., Sphaerotilus, and Bulking

Based on the foregoing, wherein sludges fed with the same sewage were subject to heavy *Sphaerotilus* growths at low oxygen concentrations, and little *Sphaerotilus* at high D.O., it may be concluded that oxygen concentration is a factor in bulking associated with this sewage fungus.

It was found in these studies that *Sphaerotilus* disappeared under anaerobic conditions. Ruehhoft and Kachmar (17) have shown that its growth is favored by increased aeration in pure culture, and in the absence of proof by bacteriologists to the contrary, this organism is held to be an aerobe. *Sphaerotilus* did flourish, however, at low oxygen concentrations in the precipitation unit. A hypothesis in explanation may be formulated as follows: The zoogleal organisms, *Sphaerotilus*, and other micro-organisms in the mixed culture of biological flocs all require oxygen, but in normal circumstances, when the oxygen tension is high, *Sphaerotilus* appears to suffer in competition with the other organisms for the available food. At low oxygen concentrations, such as 0.1 p.p.m., the metabolic activity of many of the micro-organisms, including *Sphaerotilus*, zooglea, and many protozoa, is reduced. The oxygen has difficulty in penetrating into the interior of the zoogleal masses due to the relatively limited surface area available for oxygen transfer per unit weight of organism. The zoogleal organisms suffer accordingly. The slender filaments of *Sphaerotilus*, with large surface area per unit weight, however, are still able to obtain needed oxygen. (This difference in the physical characteristics of the two organisms is demonstrated in the photomicrographs; a pure growth of zooglea may be observed in Figure 10a while *Sphaerotilus* is seen in Figure 12a.) The ability of *Sphaerotilus* to exist and grow at oxygen

concentrations as low as or lower than 0.1 p.p.m. (as long as some oxygen is present), has been demonstrated by Ruchhoft and Kachmar (17). On the basis of its survival at minimal oxygen concentrations that inhibit the growth of other organisms, the food supply falls to *Sphaerotilus*.

The filaments of *Sphaerotilus*, like the floss or fluff on milkweed or dandelion seeds, cause the sludge floc to be carried upward by small convection currents, and to "bulk." The use of air in bio-precipitation caused some "swelling" of the floc mass, which is attributed to the development of *Sphaerotilus*. (Bulking in bio-precipitation will be discussed later in the paper.)

Comparison with Activated Sludge Process

High loading of the biological floc, as shown before, increases the percentage of volatile matter in the sludge. In the activated sludge process, the increase in volatile content raises the rate of oxygen utilization and thus may seriously deplete the dissolved oxygen in the vicinity of the floc particles, although the liquid itself may still possess a measurable amount of dissolved oxygen. Such circumstances have been shown to favor the growth of *Sphaerotilus* which, with the high volatile-content sludge, may result in bulking. This condition is further aggravated by the fact that *Sphaerotilus* has a higher rate of oxygen utilization than do many of the other organisms in activated sludge (17).

Use of oxygen in bio-precipitation practically eliminates the possibility of excessive *Sphaerotilus* growth and bulking with normal sewage. The high oxygen gradient allows the oxygen to diffuse deeper into the zoogleal masses than is possible when air provides the oxygen. The highest oxygen concentration exists where it is most needed, namely, at the bottom of the precipitation unit where the load is introduced and where the activity presumably is the greatest. In the activated sludge process, on the contrary, oxygen concentration is generally lowest at the influent end of the aeration tank. (Load distribution and tapered aeration have alleviated this situation to some extent.)

Bulking in Bio-Precipitation

The presence of unusual amounts of sugar in sewage being treated by the activated sludge process is recognized to be responsible for many instances of the development of extensive growths of *Sphaerotilus* and bulking of the sludge.

Inhibition of the growth of *Sphaerotilus* in the presence of high concentrations of dissolved oxygen (up to 400 per cent super-saturation with respect to an atmosphere of air) in the preliminary experiments with activated sludge and in the bio-precipitation tests gave rise to the possibility that high concentrations of oxygen were toxic to *Sphaerotilus*, although no other aerobic organisms had been shown to be affected in this manner. It was of interest, therefore, to determine whether high oxygen concentrations would prevent extensive *Sphaerotilus* development in the presence of abnormal amounts of carbohydrates.

A sugar solution was added to the sewage being fed to one unit, keeping the B.O.D. of the sugar-rich sewage about the same as for the normal plant influent, while plain settled sewage was fed to the other unit as a control. Two runs were made (Runs 39L and 40R), in which the sugar concentrations were 62 and 166 p.p.m. of dextrose, respectively.

In each run, the floc placed in the two testing units was initially of the same batch and almost free from filamentous growths. After two days of operation, the floc in the unit fed with the sugar-rich sewage changed signally. Extensive growths of *Sphaerotilus* appeared, as can be seen in Figure 13a.

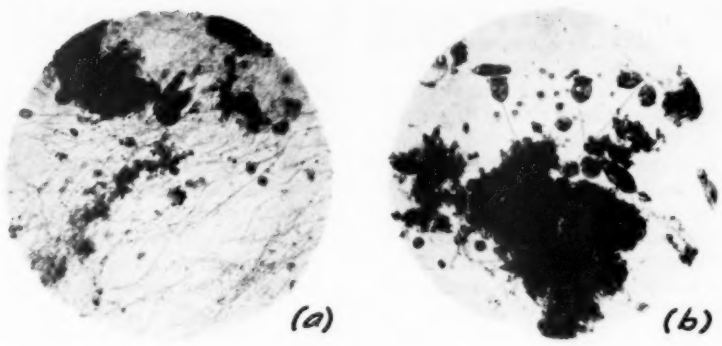


FIGURE 13.—Effect of sugar-rich sewage on biological floc: (a) floc fed with sugar-rich sewage, (b) floc fed with plain sewage [50 ×].

as compared with the control in Figure 13b, which contained no *Sphaerotilus*. The dissolved oxygen content ranged from 14 to 34 p.p.m. in the unit fed with sugar-rich sewage. The floc blanket in the latter unit became progressively "lighter" in both color and density. At one point, each gram of solids in the unit occupied 620 ml., which represents a concentration of solids of only 1,600 p.p.m., and the floc had the appearance of a bulking sludge. However, despite the serious bulking, there was no noticeable loss of floc into the effluent, which had a clear, sparkling quality. Efficiency of B.O.D. removal was not affected.

The presence of adequate oxygen for the micro-organisms at all times and the absence of the vigorous agitation associated with aeration tanks of activated sludge plants are the factors which are believed to render bulking relatively innocuous in bio-precipitation as compared with its effect in activated sludge treatment.

Carbon Dioxide in Bio-Precipitation

One of the end-products of microbial respiration is carbon dioxide, which causes the medium to become supersaturated with the gas with respect to an atmosphere of air and to be reduced in pH. However, in activated sludge aeration tanks, the continuous passage of air through the liquor tends to remove the carbon dioxide formed. Haseltine (18) found that the original pH of sewage dropped only from 7.35 to 7.31 through aeration tanks of an activated sludge plant.

In bio-precipitation there can be no removal of carbon dioxide from the liquor in the precipitation unit, except at the surface of the unit. There was, consequently, a significant pH reduction, even at relatively low loading (Run 40L, Series B), from 7.42 for the raw sewage to 6.82 for the final effluent, while the carbon dioxide content increased from about 13 p.p.m. to 45 p.p.m.

There is no evidence that a high carbon dioxide concentration, in itself, is toxic to micro-organisms involved in sewage treatment, while the presence of carbon dioxide is known to favor the growth of some bacteria. There is the possibility, however, that the carbon dioxide might reduce the pH of the medium sufficiently to effect the activity of the micro-organisms in the floc. Holderby and Lea (19) have found, for example, that at pH 5.5 to 6.0 the B.O.D. of sewage was 86 per cent of its value at pH 7.0 Butterfield (20) has

reported that zoogleal bacteria in pure culture grow within a pH range of 5.6 to 8.5, although the optimum pH is from 7.0 to 7.4.

There is little literature on the effect of pH on activated sludge treatment. Lumb (21) maintains that better clarification of sewage by activated sludge is obtained when the pH is below the isoelectric point of the sewage, which in England has been found to be about 6.5 (The optimum pH at Bradford was found to lie between pH 6.0 and 6.5.) Lumb goes so far as to suggest that acid could be used to reduce the pH of the sewage. He did find, however, that the efficiency of activated sludge treatment was reduced when the pH dropped below 6.0.

It does not appear that high carbon dioxide concentrations, or the resultant low pH, will interfere with treatment by bio-precipitation. However, this environmental factor, which is of little consequence in activated sludge or trickling filter treatment, does merit considerable study in connection with bio-precipitation.

Stage Operation

Bio-precipitation is similar to trickling filtration in that the active slimes are relatively stationary. In activated sludge treatment, on the other hand, the sludge is generally added to the sewage at the influent end of the aeration tank and travels, more or less, with the sewage to the effluent end. Little opportunity exists for extensive changes in the biological population from one end of the tank to the other during the few hours of aeration. Besides, Thomas and McKee (22) have shown that a considerable amount of longitudinal mixing occurs in aeration tanks.

Samples of floc collected from the bottom of the precipitation unit generally contained a greater concentration of micro-organisms than that from the top. The difference may be attributed to two factors: (a) settling of the individual organisms to the bottom, and (b) the greater food load at the bottom. The latter reason, it is believed, is most important, because the greater growth of protozoa in the presence of increased food load has been observed before.

It is not possible to say whether biological activity is more efficient (a) in activated sludge plants, where the sludge is brought into contact with the sewage, carried with it, separated from it, and finally returned to the influent to repeat the entire process, or (b) in bio-precipitation units or trickling filters, where each particle of floc performs the same function continuously on sewage containing about the same amount of pollute. Conditions under which the environment—including food, oxygen and turbulence—of the micro-organisms remains most stable are generally most favorable for the organisms concerned.

Attempts have been made to isolate the functions of micro-organisms in sewage treatment by introducing the principle of "stage" treatment, most common and successfully used in trickling filtration (5). Results for an experimental two-stage activated sludge plant at Calumet have been reported by Mohlman and Wheeler (23). Despite excellent treatment efficiency, they concluded that the two-stage process was biologically too sensitive and required too careful control.

To evaluate stage operation in bio-precipitation, the units were operated for a short period in series, with the floc equally distributed between the units initially (Runs 43 and 44). As was to be expected, the solids built up much more rapidly in the first stage unit than in the second, and consequently the plants were not operated so as to achieve that distribution of loading which would have yielded optimum efficiency. What that distribution is, and whether or not the units can be so operated, remains to be determined. Stage treatment resulted in 92 per cent

over-all B.O.D. removal. From Figure 7, the same load of sewage, treated in the two units in parallel, would have resulted in about 89 per cent B.O.D. reduction. As at Calumet, most of the oxidation occurred in the second stage, where most of the nitrification also took place. The volatile content of the second-stage floc dropped to 79 per cent as against 83.6 per cent in the first stage.

The microscopic life was much richer and more active in the first stage, although the same forms were found in both stages. *Sphaerotilus* was present to some extent in the first stage, but entirely absent in the second.

Oxygen Requirements in Bio-Precipitation

The methods for applying the load to the biological floc and for satisfying the oxygen requirements in bio-precipitation are essentially different from those that are used in the activated sludge process. Instead of the biological flocs being loaded discontinuously, as must be the case in activated sludge plants, even where incremental-dosing on a continuous basis is used, each element of floc is loaded continuously in bio-precipitation. There is no interval during which no load is applied, and there is no separate period for "reactivation." Bio-precipitation of pollute from the sewage proceeds concurrently with the utilization of this organic matter by the micro-organisms of the floc. Hence the oxygen utilization curve (dO/dt versus t) does not carry the significance in bio-precipitation that it does in the activated sludge process. For example, excessive rates of oxygen utilization that might occur in the precipitation unit at the point of entrance of the load do not result in disappearance of the oxygen at that point. In fact, the highest oxygen concentration is maintained where its utilization is greatest.

Measurements of oxygen utilization were made in the units themselves. The product of the difference between the dissolved oxygen concentration of the oxygenated liquor before and after passage through the suspended biological floc, and the flow factor (which is equal to the average number of passes made through the unit by an element of sewage) constitutes the oxygen utilized by the floc per unit of sewage treated.

For comparison with oxygen demand values reported for activated sludge, the oxygen utilization as found in the unit in parts per million were converted to p.p.m. per hour (dO/dt) per 1,000 p.p.m. of volatile solids. The values so obtained for each series are plotted in Figure 14a against the loading. With increased loading, the rate of oxygen utilization increased from about 10 to 40 p.p.m. per hour per 1,000 p.p.m. of volatile solids. These are average rates of respiration for all the floc in the unit. Determination of the rate at various points in the unit as the sewage passes upward through the floc mass would establish an oxygen utilization curve for bio-precipitation. The shape of such a curve would not necessarily be the same as the oxygen utilization curve for activated sludge. The degree of stabilization and the so-called "base rate" of oxygen utilization, which is never physically attained in bio-precipitation, would be different at each level.

A comparison of the average respiration rates found in bio-precipitation with those experienced in activated sludge plants may nevertheless be of interest. Bloodgood (24) has considered oxygen utilization rates of activated sludges as satisfactory when their "base rate" lay between 5 and 10 p.p.m. per hour per 1,000 p.p.m. suspended solids, and when their initial increase in rate on addition of the sewage was between 14 and 20 p.p.m. per hour per 1,000 p.p.m. suspended solids. Adding these values, and adjusting them to an 80 per cent volatile content of the sludge, the oxygen utilization

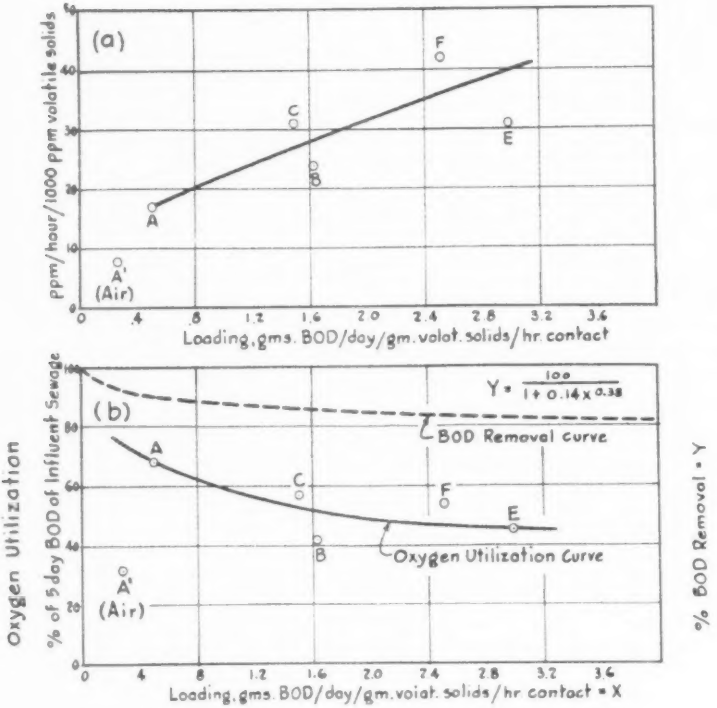


FIGURE 14.—Oxygen utilization relations in bio-precipitation.

rates for mainfenance of satisfactory sludge conditions lie between 24 [3] and 38 [4] p.p.m. per hour per 1,000 p.p.m. volatile solids. These are maximum rates, which occur after addition of the sewage load, the average rate for the period of aeration being considerably lower. In bio-precipitation, it was found possible to maintain an average rate of 40 p.p.m. per hour per 1,000 p.p.m. volatile solids, without deterioration of the floc.

A convenient method for reporting the oxygen utilization is in terms of the 5-day B.O.D. of the applied sewage. For the runs with oxygen it is seen in Figure 14b that at increasing loadings the oxygen requirements of each unit of sewage decreased from 68 per cent at low loadings to less than 50 per cent of the 5-day B.O.D. at high loadings. This decrease may be attributed in part to the lesser amount of nitrification and oxidation at the higher loadings. With air, where no nitrification took place, the oxygen requirements were only 32 per cent of the 5-day B.O.D. Some part of the decrease in oxygen requirements with increase in loadings may be assigned to the lesser degree of removal of pollute from the sewage at the higher loadings.

The oxygen consumption by the non-nitrifying activated sludge used by McKee and Fair (2) was about 75 per cent of the 5-day B.O.D. of the raw,

[3] $\frac{5+14}{0.80}=24$.

[4] $\frac{10+20}{0.80}=38$.

unsettled sewage in 5 hours. Analysis of the information reported by Ruchhoft, McNamee, and Butterfield (25) indicates that the total oxygen consumption in 5 hours of aeration with a non-nitrifying activated sludge to which normal sewage has been added varies from 57 to 100 per cent of the 5-day B.O.D. They have shown, further, that with nitrifying sludges the oxygen consumption can easily exceed 100 per cent of the 5-day B.O.D. of the sewage added.

It may be concluded that, although the oxygen requirements of each unit weight of floc in bio-precipitation are greater, in general, than that of activated sludge, the total oxygen requirements of the process are less than in activated sludge treatment.

In operating the laboratory bio-precipitation units, no attempt was made to attain high efficiency of oxygen absorption from the gaseous oxygen applied. Despite this, the efficiency ranged from 10 to 50 per cent, and averaged about 30 per cent, as compared with only 5 to 10 per cent efficiency attained in activated sludge aeration tanks.

Summary

The results of experimental investigations made with the bio-precipitation apparatus are summarized below:

(1) Efficiency of B.O.D. removal is a function of the weight of volatile matter in the biological floc present in the system. A greater weight of volatile solids in the precipitation unit results in a higher degree of purification. Where the per cent volatile matter in the sludge is relatively constant, the efficiency may be taken as a function of the total weight of solids.

(2) Provision of the requisite oxygen for the biological flocs by pre-oxygenation of the influent with oxygen makes possible the maintenance of a concentration of biological floc in the system more than twice as great as that possible in the aeration tanks of activated sludge plants. Adjustment of the turbulence in the precipitation unit may permit still higher sludge concentrations.

(3) Because each unit volume in the precipitation device can carry a greater weight of biological floc than is possible in a conventional aeration tank, and because the efficiency of B.O.D. removal increases with increase in weight of floc, it is concluded that, for equivalent sewage purification, a smaller plant capacity is required in bio-precipitation treatment than in activated sludge treatment.

(4) In order to attain an equal, high degree of sewage treatment, the volume of the structure required to hold the biological floc in bio-precipitation is only about one-fourth the volume of aeration tanks necessary for the activated sludge process. For "intermediate treatment" the volume needed for bio-precipitation is less than one-fourth the aeration tank volume in high-rate activated sludge plants.

(5) The per cent reduction in B.O.D. decreases with increased loading (weight of B.O.D. applied per day) of the biological system.

(6) An over-all loading parameter is used to assess the performance of the bio-precipitation unit in much the same way as has been done for activated sludge plants. The following relation was established between loading and efficiency of B.O.D. removal

$$\text{B.O.D. Removal } (\%) = \frac{100}{1+0.14X^{0.38}}$$

where X is the loading in weight of B.O.D. applied per day per unit weight of volatile solids per hour contact.

(7) The rate of growth of biological floc per unit of applied sewage is greater at higher loadings, despite the fact that a lesser portion of pollute is precipitated from the sewage under conditions of high loading.

(8) The volatile content of the biological floc increases at higher loadings. It is concluded that a greater degree of

oxidation of adsorbed organic matter occurs at lower loadings.

(9) A lesser degree of nitrification occurs at higher loadings.

(10) Conditions conducive to "blanket rising" of sludge in the final settling tanks of activated sludge plants, i.e., reduction of nitrites and nitrates to gaseous nitrogen due to lack of oxygen, do not exist in bio-precipitation units.

(11) Differences in loading do not result in marked differences in the microscopic life of the biological flocs, except that the number and activity of the protozoa are greater at higher loadings.

(12) When sufficient oxygen is continuously available to the micro-organisms, high loading does not result in deterioration of the biological floc.

(13) Air can be used for pre-oxygenation of sewage, instead of oxygen, at low loadings, with no detriment to treatment efficiency. However, higher recirculation rates are necessary, and the sludge is somewhat difficult to control.

(14) The low oxygen concentrations associated with the use of air inhibit nitrification.

(15) Extensive growths of *Sphaerotilus* occur at low oxygen tensions, although this organism is entirely absent at high oxygen concentrations under the same conditions of loading. This higher bacterium disappears with onset of anaerobic conditions.

(16) Conditions that cause low oxygen concentrations in biological treatment, such as high loadings, are responsible for the growth of *Sphaerotilus*. The presence of extensive filaments of *Sphaerotilus*, in addition to the higher volatile content of the sludge due to the higher loading, result in "bulking."

(17) The presence of abnormal amounts of sugar in sewage encourages the development of *Sphaerotilus* growths, and results in bulking, even under high oxygen tensions. Bulking did not impair purification by bio-precipitation, however. This is attributed to the presence of adequate oxygen without excessive agitation.

(18) Treatment of sewage by pre-oxygenation and upward passage through suspended biological floc does not facilitate escape of the carbon dioxide formed by the microbial metabolism. Consequently, there is a drop in pH as the sewage passes through the plant. There is no conclusive evidence that the presence of carbon dioxide, or the low pH resulting from it, are especially beneficial or detrimental to the biological treatment process.

(19) Protozoa are present in greater numbers and are more active in the biological floc at the bottom of the precipitation unit than at the top. The difference is more marked between the biological flocs in the first and second stages of two-stage treatment.

(20) The operation of two units in series offers promise of greater efficiency than is possible by operation of the units in parallel.

(21) Oxygen utilization in bio-precipitation increases with increased loading from about 10 to 40 p.p.m. per hour per 1,000 p.p.m. of volatile solids. The total oxygen requirement varies from 50 to 70 per cent of the 5-day B.O.D. of the sewage treated, increasing at lower loadings. Although the rate of oxygen utilization was found to be higher than that normally experienced with activated sludge, total oxygen requirements for bio-precipitation were less.

(22) The total oxygen requirements of the process are met by pre-oxygenation of the influent liquor to the precipitation unit. Excessive rates of oxygen utilization that might occur in the precipitation unit at the point of entrance of the load do not result in disappearance of the oxygen at that point. In fact, the highest oxygen gradients are maintained where the oxygen utilization is the greatest.

Conclusion

The results obtained in this study are of sufficient promise to warrant consideration of bio-precipitation, using low-cost "tonnage" oxygen, as a means for sewage treatment. It is not the purpose of this paper to enter into an analysis of the relative costs of bio-precipitation and activated sludge treatment, such analysis being premature until data are available from a pilot plant installation. For a high degree of treatment, however, application of the principles of bio-precipitation appears to offer three- to four-fold savings in plant requirements over those for the activated sludge process, with greater economies to be expected for intermediate treatment of sewage by bio-precipitation.

Acknowledgment

The material for this paper was abstracted from parts of a thesis presented by the author in partial fulfilment of the requirements for the degree of Doctor of Science in the Graduate School of Engineering of Harvard University. Acknowledgment is gratefully made to Dean Gordon M. Fair and the faculty of the Department of Sanitary Engineering for their generous assistance and guidance in the prosecution of this investigation.

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DISCUSSION

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This is a remarkable piece of work for a laboratory investigation and has many unique and informative aspects not heretofore found in such work. For example, the experiments were on a continuous basis, sludge formation and growth were measured, sludge index was determined, loadings were accurately controlled, and biological observations were quite extensive. More comparisons of air *vs.* oxygen, which are shown only in Runs 32, 33, and 34, would be desirable to afford convincing proof that oxygen permits rates four or five times those possible with air. However, such proof can wait on further pilot-plant tests. For laboratory studies, it is difficult to suggest any improvements on the technique and results reported by Dr. Okun.

First, it seems well-proven that the sludge density is considerably greater with oxygen than with air, and the claims are well-substantiated that more solids, thus more surface, can be carried in the system. This allows the period to be shortened, but not directly inversely with the weight of solids. Next, sludge was apparently maintained in good condition with very short periods of 30 min. (loadings of 320 lb. B.O.D. per 1,000 cu. ft. per 24 hr.), ascribed to the presence of oxygen, and without any reaeration. Bio-

TABLE I.—Comparison of Air and Oxygen (Okun, 1947)

Run	Flow (cc./min.)	5-day B.O.D.			Nitrate N Eff. (p.p.m.)	Density (Index)	Ox. Util. (p.p.m.)	Remarks
		Raw (p.p.m.)	Eff. (p.p.m.)	Per Ct. Red.				
32	11.7	211	14.6	93.1	Tr.	250	68–72	Air
	12.8	211	10.8	94.9	3.2	130	108–198	Oxygen
33	12.4	177	13.6	91.9	0	280	57	Air
	12.4	170	14.7	91.2	2.2	120	141	Oxygen
34	12.6	177	13.1	92.6	0	210	51	Air
	14.2	177	9.1	94.8	1.0	230	124	Oxygen

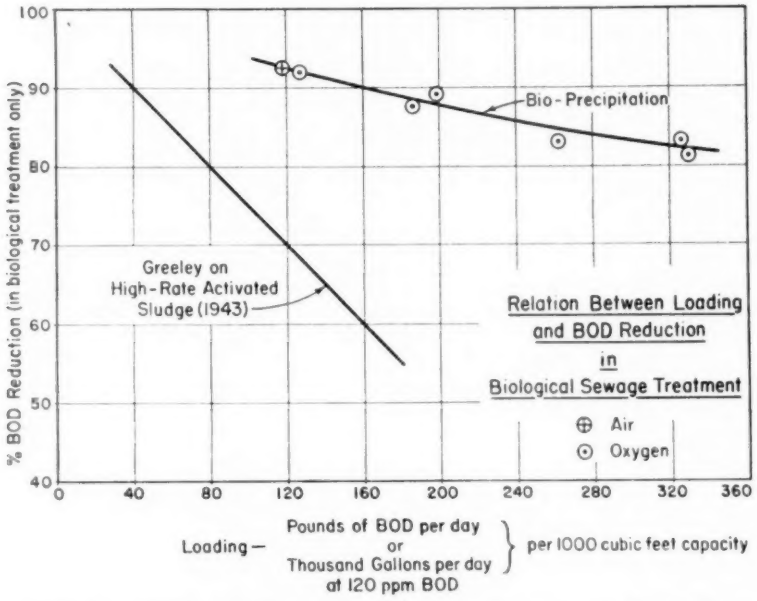

FIGURE 1.—Relation between loading and B.O.D. reduction; comparison of bio-precipitation with activated sludge.

logical properties of the sludge remained excellent, with little *Sphaerotilus* and no gas-lifted sludge due to nitrates. Loadings suggest the rates may be four times normal values.

Comparisons of air and oxygen are shown in Table I. These are at high rates—about 2.4-hr. aeration—but even at this forced labor the oxygen tests produced an average of 2.1 p.p.m. nitrates and 93.3 per cent B.O.D. reduction. However, the control using air also gave 92.5 per cent B.O.D. reduction. This result is shown in Figure 1 as the point at 93 per cent reduction and 120 lb. B.O.D. loading. The question arises: Why is this four times as high as the 93 per cent point on Greeley's curve? Apparently the laboratory tests, even with air, operated at rates far above those noted in operating plants. This raises a question concerning the claims of four-fold loadings. Why should such high rates be obtained with air? Why weren't parallel experiments run, in which air was used in one aerator and oxygen was used in the other aerator at four-fold loadings? The oxygen results in Figure 1 can hardly be compared with Greeley's loadings to prove the possibility of such enormous rates, when air alone seemed to give four times the rate normally noted with 93 per cent removals.

Higher loadings shown in Table II resulted in depreciation of effluents, but in general sludge density remained as low as at the one-fourth loadings, even with periods as low as 30 min. This indicates that as a bio-precipitation process, the oxygen-supplied sewage may be treated at excessive rates.

If the high rates noted in the experimental work are ascribed to maintenance of large concentrations of solids in the system, in the case of air this must have been possible because

TABLE II.—Low and High Rate Treatment with Oxygen (Okun, 1947)

Run	Flow (cc./min.)	5-day B.O.D.			Nitrate N Eff. (p.p.m.)	Density (Index)	Ox. Util. (p.p.m.)	Remarks
		Raw (p.p.m.)	Eff. (p.p.m.)	Per Ct. Red.				
26	9.4	105	13.0	87.6	4.2	220	56–88	Oxygen
	50.2	105	26.0	75.3	1.8	260	48–64	Oxygen
27	10.4	159	13.4	91.5	4.3	190	50–66	Oxygen
	50.4	159	35.8	77.6	0.4	260	60–68	Oxygen
28	12.6	131	12.6	90.5	—	330	57–98	Oxygen
	53.8	131	22.5	82.8	—	310	46–53	Oxygen
29	12.5	129	12.3	90.5	7.2	260	44–58	Oxygen
	50.4	129	18.4	85.8	—	280	54–65	Oxygen
31	11.9	112	7.4	93.5	—	320	131	Oxygen
	48.8	112	20.0	82.2	—	140	70	Oxygen

of the use of the oxygenating column and the reaction tube. (However, with air the solids concentrations in the mixed liquors were only 3,500 to 4,800 p.p.m.—not much greater than used at Milwaukee, for example.)

It will be of interest to see how the technique of this work can be translated into practical operating columns or tanks of a full-scale plant. This will require much ingenious development even before costs are estimated. The design will be radically different from present activated sludge plants. Whether such small laboratory tubes can be enlarged to operating tanks or columns remains to be determined. Next will come the questions: How much oxygen? How will solids be kept in suspension? How much recirculation is necessary? Can settling tanks be dispensed with? What will the oxygen cost?

However, the practical difficulties that have been cited seemed equally insurmountable when Ardern and Lockett first announced their laboratory results on activated sludge, and it may be that it will take as much or more practical development to perfect Dr. Okun's procedure. The interesting facts proven by him concerning the density of oxygenated sludge seem to bear a relation to the trend toward higher solids and lower index as exemplified by Kraus' activated sludge procedure, Zigerli's asbestos process and possibly some phases of the Guggenheim process. In any of these modifications, many questions of economies must be answered, and these are the next hurdles to be surmounted by the oxygen process.

It is evident that the scope of the present laboratory work is adequate to explore only the chemical and biological features of the use of oxygen, and is not on a large enough scale to define the exact amount of oxygen required nor the capacities required. Therefore, there is no discussion of the design of the radically different type of plant required, the production and cost of oxygen, nor the over-all costs as compared with normal air-operated plants.

SLUDGE ODOR CONTROL BY DIESEL OIL SCRUBBING

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At the Wards Island sewage treatment plant in New York City the primary and waste activated sludge are stored in large open tanks in a closed building before being loaded on the sludge vessels for discharge at sea. The air above the tanks becomes very foul and must be deodorized before it is released to the atmosphere. This is now accomplished by ozonation.

Preliminary tests with the Pease-Anthony scrubber, which has been used successfully for the removal of dusts, fumes, and smokes, indicated that water alone was ineffective, but that the foul odors could be removed by scrubbing the air with alkalies or with light oils of the kerosene or diesel oil type. The theory of the scrubber's operation has been discussed in several articles (1) (2) (3) (4) (5). Concurrent with these preliminary tests, Dittmer (6) demonstrated that this type of wet cyclone scrubber, using water, could satisfactorily remove fumes and acrolein from the cooking of linseed oils. Some experimental work has been done (5) on the removal of odors from a vaporized fatty material.

In the scrubber the foul air, rotating rapidly in a cylindrical chamber, comes in contact with a spray or fog of fine liquid, which absorbs the odors. The sprayed liquid collects on the wall of the scrubber, from which it is washed and discharged. The number and size of the spray nozzles and the liquid pressure are selected to furnish the quantity and fineness of spray necessary. As shown schematically in Figure 1, the foul air enters tangentially at the bottom of the cylinder and is discharged at the top. The liquid is sprayed from nozzles on the vertical header.

A scrubber of galvanized sheet metal, 17 in. in diameter and 74 in. high, was put into service in March, 1947. A spray header pipe was fitted with 12 spray nozzles having 0.050-in. diameter orifices. The velocity of the air was

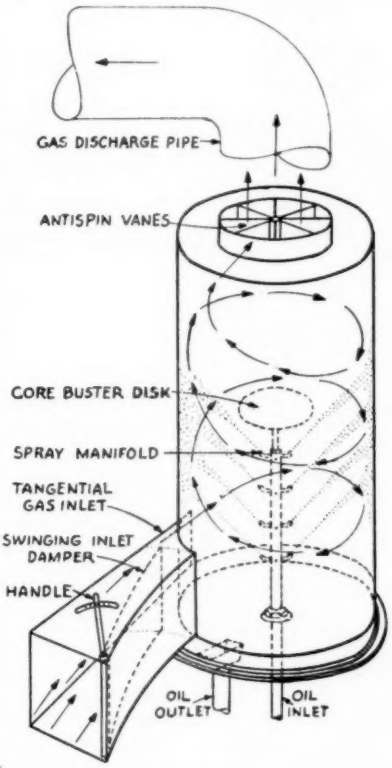

FIGURE 1.—Schematic view of air scrubber using diesel oil for odor removal.

TABLE I.—Data on Odor Removal by Diesel Oil in Scrubber

Date 1947	No. 3 Diesel Fuel Oil						Air Flow		
	Additional Agent	Amount (gal.)		Loss (gal. per mil. cu. ft. air scrubbed)	Rate of Recirculation (g.p.m.)	Pressure (p.s.i.)	Rate (c.f.m.)	Total (cu. ft.)	C.f. gal. Oil
		Start	Final						
4/23 to 4/29	None	10	7	4.37	2.4	15	415	686,100	68,600
4/30 to 5/15	None	11	6.5	4.77	3.0	18	410	1,038,000	94,400
5/22 to 6/2	None	10	6.5	3.58	3.2	20	410	977,850	97,785
6/6 to 6/16	None	10	6.1	3.94	3.5	20	410	989,000	98,900
9/3 to 9/11	None	10	6.0	4.27	3.0–3.6	20	405	937,200	93,720
9/29 to 10/10	70 ml. nitrobenzene	10	6.3	3.27	3.1–3.9	20	405	1,129,950	113,000
10/15 to 11/7	300 g.[1] naphthalene	10	5.8	2.03	2.8–3.9	20	405	2,065,500	206,550
11/25 to 12/24	250 g.[2] naphthalene	10.625	6.6	1.97	3.3–4.0	20	405	2,539,300	238,000

[1] 300 grams of naphthalene and p-dichlorbenzene mixture dissolved in 1.5 liters of xylol.
[2] 250 grams of naphthalene in 0.625 gal. of kerosene.

controlled by a damper at the inlet to the scrubber.

In making a test, 10 gal. of diesel oil were placed in the recirculating tank. The oil was used to scrub the air until it became fouled or until the oil level in the tank became so low, because of evaporation or carry-over of minute oil fog, that the pump sucked air. The oil was recirculated at the rate of 2.4 to 4.0 g.p.m. at a pressure of 20 p.s.i. The rate of air flow was about 410 c.f.m.

High Evaporation Losses

The first test made with this new scrubber indicated that the odors could be removed economically with diesel fuel oil. As shown in Table I, the loss of oil by evaporation was high, with a rate of 4.37 gal. per million cubic feet of air scrubbed. The quantity of air scrubbed was 68,600 cu. ft. per gallon of oil. The foul sludge odor was removed, leaving a slight kerosene-like odor.

The first test was concluded because of the loss of oil through leaks, fog, and evaporation in the discharged air. In the following four runs, the leaks were stopped and the average amount of air scrubbed was 96,200 cu. ft. per gallon of oil. The losses, however, remained at more than 4 gal. per million cubic feet of air scrubbed. In an attempt to reduce the losses six screens (about 10 mesh) were placed in the air discharge pipe to condense the oil fog. The amount of oil recovered was not significant.

In order to decrease the residual hydrocarbon odors, various essential oils were used as masking agents. The kerosene-like odors could be successfully covered, but the improvement did not seem commensurate with the cost.

Efforts to Reduce Oil Evaporation

Nitrobenzene has been used for the elimination of disagreeable odors and a trial in the spray scrubber seemed justified. The nitrobenzene was added in proportions of 5 to 15 ml. per 10 gal. of oil as needed during the course of the test. Only a slight odor of nitrobenzene was observed, but the odor of diesel oil decreased markedly. As shown in Table I, a total of 70 ml. of nitrobenzene was added to the 10 gal. of oil during the test. The nitrobenzene not only reduced the oily odor, but it also decreased the vapor pressure of the oil and less evaporation took place. In this test, 113,000 cu. ft. of air were treated per gallon of oil added

initially, an increase of about 18 per cent over the amount treated without nitrobenzene. The loss in gallons of oil per million cubic feet of air treated dropped from 4.14 to 3.27. Nitrobenzene, however, is a poison and its vapors are considered an industrial hazard.

Naphthalene containing a small amount of p-dichlorbenzene was tried next. The naphthalene, dissolved in xylol, was added to the diesel oil in 3 doses of 100 grams each at the beginning of the test and at about one-third and two-thirds through the run. The naphthalene was also satisfactory in reducing the odor of the diesel oil and was far superior to nitrobenzene in decreasing the vapor pressure of the oil. The loss by evaporation decreased to about 2 gal. per million cubic feet of air scrubbed and the amount of air treated per unit of oil nearly doubled. Undoubtedly, part of the increased length of run was caused by the decreased evaporation, which permitted a run of 85 hr. instead of the customary 40 hr. before the pump sucked air.

A second test was made with diesel oil using naphthalene only, dissolved in kerosene. The results, as shown in Table I, were about the same as with the mixture of naphthalene and p-dichlorbenzene. The cubic feet of air treated per gallon of oil increased to 238,000 and the loss of oil by evaporation remained at 2 gal. per million cubic feet of air.

The ventilating fan in the sludge storage building has an air capacity of 15,000 c.f.m. If, as indicated by the tests, 1 gal. of diesel oil with naphthalene can remove the odor from 200,000 cu. ft. of gas about 110 gal. of oil and 6 lb. of naphthalene would be required each day. With diesel oil at 6¢ per gallon, and naphthalene in large quantities at 5¢ per pound, the cost per day for absorbing agent is $6.90.

Oil Not Harmed by Naphthalene

Analyses showed that the used oil containing naphthalene meets the specifications of the Department of Purchase for No. 3 diesel fuel oil. As shown in Table II, the carbon residue,

TABLE II.—Analyses of No. 3 Diesel Fuel Oil

	Specifications	Oil Used in Experiments			
		New	Used	Used, with Naphthalene and P-dichlorbenzene	Used, with Naphthalene
Flash point (° F.)	Min. 125	Above 150	Above 150	Above 150	Above 175
Pour point (° F.)	Max. 35	Below 20	Below 20	Solidifies at 6° F.[1]	Below 20
Water and sediment (%)	Max. 0.10	0.05	0.1	<0.10	<0.10
Carbon residue (%)	Max. 0.50	0.002	0.047	0.019	0.30
Viscosity S.U. at 100° F. (sec.)		35.7	39.4	39.4	38.24
Sulfur (%)		0.48	0.47	0.45	0.45
Diesel Index No.		56.6	56.9	57.8	55.8
Ash (%)		0.002	0.003	0.007	0.009
A.P.I. gravity at 60° F.		36.3	34.7	—	—
Aniline Point (° F.)		150	164	—	—
Corrosion (4 Days at 95° F.)					
Stainless steel, plain		No effect	No effect	No effect	—
Steel, Cast iron, Copper					
Chlorine as Dichlorbenzene (%)		—	—	0.066	—

[1] Precipitation of one or more components begins at 36° F. and continues steadily until, at 6° F., the whole is a solid mass.

the viscosity, and the ash increased slightly, but no increase in sulfur or in corrosive properties was found.

Inasmuch as the loss of oil by evaporation amounts to 2 gal. per million cubic feet of air scrubbed, the loss per day in the full scale operation would be 43 gal., leaving 67 gal. available for use as fuel in the sludge vessels. The net cost per day for oil, therefore, is reduced to $2.60, or $2.90 including the naphthalene.

The addition of a small amount of an essential oil will completely mask any slight residual hydrocarbon odor. Under ordinary circumstances, the odor of the air discharged from the scrubber would be satisfactory without further treatment. The concentration of oil in the air discharged from the scrubber would be far below that required for an explosive mixture, which would probably result when the concentration of oil vapor reached the range of 1 to 6 per cent by volume.

Summary

The experimental scrubber has successfully removed the foul odors from the air in the sludge storage room at the Wards Island sewage treatment plant by scrubbing with No. 3 diesel fuel oil and a small quantity of naphthalene (0.55 lb. in 10 gal. oil). A very slight kerosene-like odor remains. One gallon of oil will remove the odor from about 200,000 cu. ft. of air. The naphthalene reduces the evaporation of the diesel oil and permits a larger amount of air to be treated per unit of oil. The loss of oil by evaporation amounts to about 2 gal. per million cubic feet of air scrubbed. According to analysis, the spent oil still meets the Department of Purchase specifications for No. 3 diesel fuel oil and it could be used in the diesel engines of the sludge vessels. The net cost of oil and naphthalene to remove the odors from the sludge storage building at Wards Island would amount to about $3 per day.

Acknowledgment

The advice and assistance of Mr. A. W. Anthony, Jr., president of Pease-Anthony Equipment Company, was very helpful in carrying out the tests described herein.

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SCUM REMOVAL BY VACUATOR AT PALO ALTO*

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Development Dept., The Dorr Company, New York, N. Y.

Since the construction of the original Palo Alto, Calif., sewage treatment plant in 1934, cannery wastes have been a perennial and increasing obstacle to proper operation. The chief difficulty encountered was the excessive amount of scum formed on the clarifier surface. At times during the cannery season sufficient scum was formed to overwhelm completely the skimming arrangement on the tank, so that it was necessary for the operators to work day and night skimming the tank by hand. Obviously such a condition must have an adverse effect on the quality of the plant effluent. During the 5-month canning season apricot, peach, pear, and tomato wastes amounting to 50 per cent of the domestic sewage flow are received from the single cannery in town.

Because of the difficulties experienced with these wastes an expansion program—consisting of the modification of the existing circular cross-flow clarifier to a center-feed clarifier, the addition of another digester and a high-rate roughing filter, and the installation of a Vacuator—was completed in 1948. The Vacuator, installed primarily as a means of control of the scum conditions on the clarifier, was the subject of a 3½-month study during the 1948 canning season. It is the purpose of this paper to present some of the results obtained.

The Vacuator (Figure 1) operates on the principle of vacuum flotation and is designed to encourage scum for-

* Presented at 1949 Annual Meeting, California Sewage Works Association; Stockton, Calif.; May 19–21, 1949.

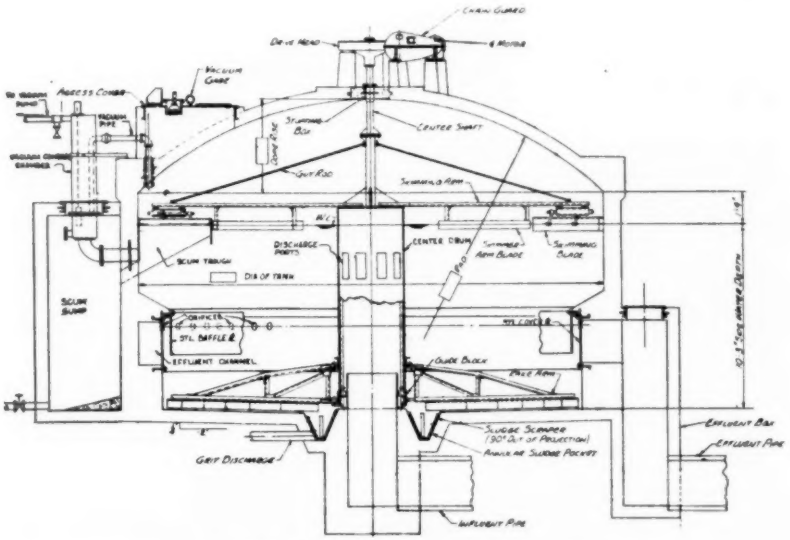

FIGURE 1.—Sectional elevation of Vacuator.

mation where it can be handled properly. Briefly the unit is a covered cylindrical concrete tank, into which sewage is admitted by means of a central draft tube. In the tank the sewage is subjected to a vacuum equivalent to 9 in. of mercury, maintained by a small wet vacuum pump. Just prior to its admission to the tank the sewage is aerated by means of a mechanical aerator. Large bubbles of air are removed by momentary detention in a well, but the smaller bubbles do not rise appreciably until they are expanded by the influence of the vacuum. Thus, within the Vacuator they rise at a proper rate and in doing so attach themselves to suspended solids carrying them to the surface to form a thick scum. An efficient skimming arrangement continuously transfers the scum to a sump, from which it is pumped to a digester or other means of disposal. Heavier material, such as grit or large organic solids, settles to the bottom of the tank, where it is raked to a sludge sump. Treated sewage leaves the unit through a submerged effluent launder. The water level in the tank is elevated in accordance with the vacuum to which it is subjected, so that the flow in and out of the unit is similar to the flow of a liquid through a siphon. No work other than that required to overcome the small head loss is expended in elevating the sewage.

The Palo Alto Vacuator is 35 ft. in diameter and has a side water depth of 10 ft. 6 in. (Figure 2). Special considerations at Palo Alto made it desirable to have the tank elevated to the extent shown. The space under the unit is effectively used to house sludge pumping, digester heating, and chlorination equipment.

Operating Results

The test program at Palo Alto was planned to coincide with the canning season. Due to the lateness of crops, an opportunity was presented to test the unit on domestic sewage alone for about three weeks. During practically the entire 3½-month test period the Vacuator served as the sole primary unit ahead of the roughing filter, with

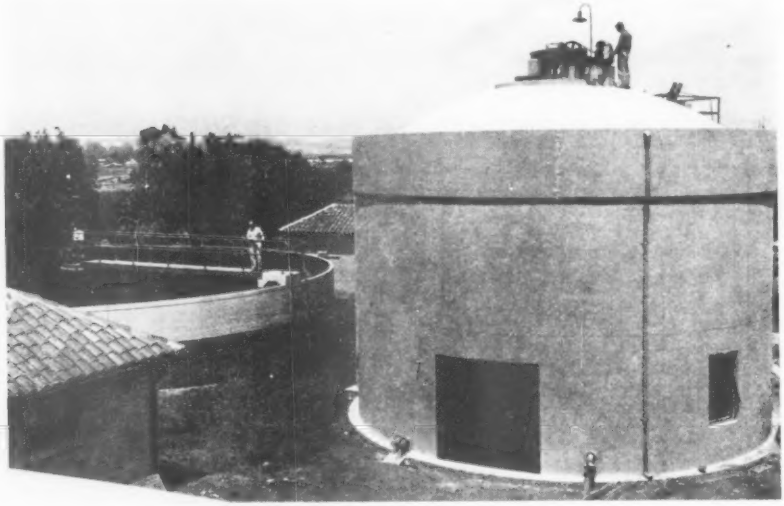

FIGURE 2.—Elevated Vacuator unit at Palo Alto.

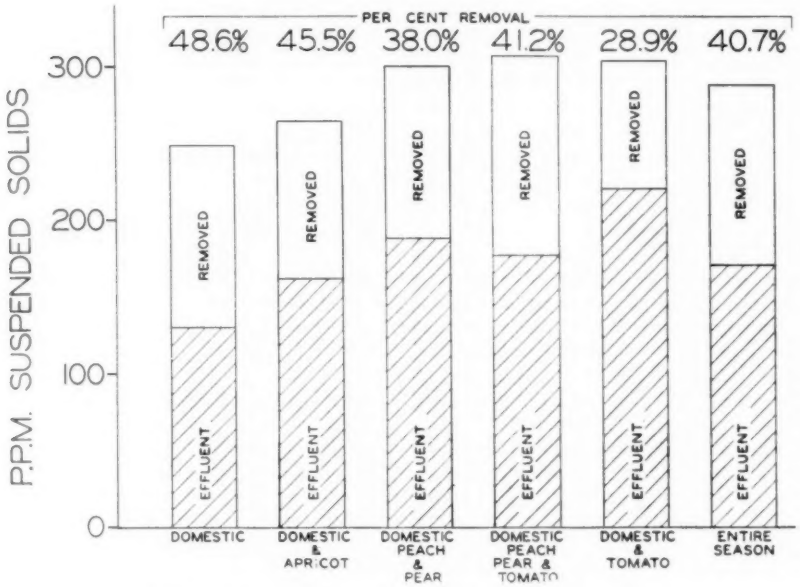

FIGURE 3.—Removals of suspended solids in Vacuator.

the clarifier serving as a secondary settling tank. Because of the fact that the roughing filter was put into service at a time coinciding with the onset of the canning season, the filter was very heavily loaded and did not have an opportunity to mature during the test program. Consequently, the bulk of the burden of purification was thrown on the Vacuator and secondary clarifier.

Regular tests conducted to determine the Vacuator performance included suspended solids and B.O.D. of the influent and effluent. Except for a few periods, settleable solids by weight were also determined on the influent and effluent. Sampling points were carefully chosen. Fortunately, samples of both the influent and effluent could be taken after a fall over a weir.

All results obtained, except those concerning the character of the scum and sludge produced are based on hourly samples from 4 P.M. to 8 A.M. and, for the most part, on half-hourly samples taken during the day shift. Samples from each 8-hr. shift were composited on the basis of flow and analyzed. The results from each 8-hr. period were then averaged on a flow-weighted basis to give the daily results. Samples were not collected over week-ends. For purposes of this paper the daily results were averaged to give weekly results, and these in turn averaged to give results over periods during which the various types of cannery wastes were received at the plant.

The suspended solids results are shown in Figure 3. The over-all length of the bar represents concentration of the influent, the shaded length represents concentration of the effluent and the white portion represents the amount removed. Percentage reductions are shown over each bar. With domestic sewage the removal was nearly 50 per cent; with all wastes ex-

cept straight tomato wastes, approximated 40 per cent. The over-all average for the entire season was 40 per cent. It should be emphasized at this point that all cannery wastes were prescreened through a 40-mesh screen at the cannery. Therefore, the solids reaching the sewage treatment plant were of a more finely divided nature and of a lower concentration than might be encountered if there were no screening or if a coarser screen were used. Under the existing conditions, the percentage reductions obtained were less than would be encountered if the cannery wastes had not been prescreened. The only waste mixed with sewage which gave removals much under 40 per cent was that from tomato canning, which showed a removal of 28.9 per cent.

An opportunity arose to study the efficiency of a Vacuator preceding a clarifier during a 2-week period when the roughing filter was out of service. Domestic sewage only was treated. During this period the average overflow rate through the Vacuator was 2,185 g.p.d. per sq. ft.; through the clarifier, 880 g.p.d. per sq. ft. The following suspended solids results were obtained:

Treatment	Raw Sewage (p.p.m.)	Effluent (p.p.m.)	Reduction (%)
Vacuator	251	127	49.4
Vacuator plus	—	74	70.5

Removals of settleable solids by weight were considered to be of importance because no gravity separation device such as a clarifier or Vacuator can be expected to remove more than the settleable solids. This test was conducted by determining suspended

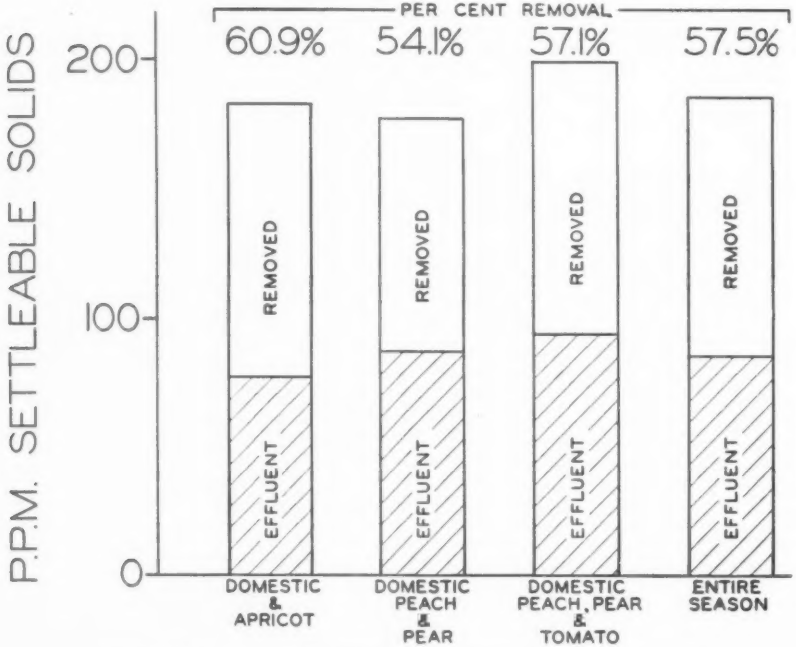

FIGURE 4.—Removals of settleable solids (by weight) in Vacuator.

TABLE I.—Average Results for Various Cannery Wastes Received at Palo Alto

Period	Character of Waste	Type of Samples[1]	Flow (m.g.d.)	Overflow Rate (g.p.d./sq. ft.)	Suspended Solids			Settleable Solids			B.O.D.		
					Infl. (p.p.m.)	Effl. (p.p.m.)	Red. (%)	Infl. (p.p.m.)	Effl. (p.p.m.)	Red. (%)	Infl. (p.p.m.)	Effl. (p.p.m.)	Red. (%)
July 1–23	Domestic	24-hr.	2.06	2,140	249	128	48.6	—	—	—	202	166	18.9
		8-hr.	2.58	2,690	296	138	53.4	—	—	—	221	182	17.6
July 26–Aug. 6	Domestic and 1 m.g.d. apricot	24-hr.	2.94	3,060	266	145	45.5	174	68	60.9	305	264	13.4
		8-hr.	3.57	3,700	325	168	48.3	215	82	61.9	295	248	15.9
Aug. 9–13 and Aug. 30–Sept. 10	Domestic, peach, and pear	24-hr.	2.68	2,790	300	186	38.0	170	78	54.1	610	571	6.4
		8-hr.	3.14	3,270	365	217	40.5	225	108	51.9	606	588	3.0
Sept. 13–17	Domestic, peach, pear, and tomato	24-hr.	3.14	3,270	303	178	41.2	198	85	57.1	792	722	8.8
		8-hr.	3.58	3,730	292	166	43.1	193	84	56.5	748	692	7.5
Sept. 20–24[2]	Domestic, peach, and recirculation	24-hr.	5.38	5,600	299	226	24.4	—	—	—	448	429	4.2
		8-hr.	5.91	6,150	322	207	32.6	—	—	—	405	380	6.1
Sept. 27–Oct. 12	Domestic and tomato	24-hr.	2.97	3,090	301	214	28.9	—	—	—	416	383	7.9
		8-hr.	3.57	3,710	360	234	35.0	—	—	—	434	403	7.0
Over-all average[3]		24-hr.	2.75	2,860	285	169	40.7	181	77	57.5	467	422	9.6
		8-hr.	3.29	3,410	328	185	43.6	211	91	57.0	461	423	8.4

[1] 24-hr. composites and 8-hr. daytime composites.
[2] All filter effluent recirculated through Vacuator to increase overflow rate; discontinued because of extreme pump surges.
[3] Results for recirculation period (Sept. 20–24) omitted.

solids in a sample, settling it for 1 hr. in a liter graduate and siphoning off a sample for suspended solids analysis. The difference between the two results was taken as the settleable solids by weight. Admittedly subject to error, the test was nevertheless considered a good indication of performance. Results of the settleable solids test are shown in Figure 4. The test was not run during the period when only domestic sewage or domestic sewage and tomato wastes were being received at the plant. The graph indicates that removals of 55 to 60 per cent may be expected.

B.O.D. removals through the Vacuator were, as expected, low. With domestic sewage a removal of 18.9 per cent was obtained, but during periods when cannery wastes were received the removals ranged from 6.4 to 13.4 per cent. In view of the fact that the B.O.D. at these times approached an average of 800 p.p.m. and was more than double the suspended solids content, low removals were to be expected. A summary of the results obtained during the various phases of the canning season is given in Table I.

At this point it is pertinent to examine the performance of the Vacuator in light of the volumetric loading imposed. The Palo Alto unit was designed for an average overflow rate of 5,000 g.p.d. per sq. ft., at which flow rate a detention of about 11 min. would be provided. Inasmuch as the plant was designed for the future, this loading was not obtained during 1948. Actually, an average overflow rate of only 40 per cent of the design rate was prevalent during the time when domestic sewage only was received, and about 60 per cent of the design rate during the canning season. However, if only the daytime flows are considered, overflow rates of about 75 per cent of the design rate prevailed during the time when apricot wastes, and peach, pear and tomato wastes were received in the sewage. Separate analyses were made of the daytime flows; in each instance results were obtained equal to or better than the 24-hr. results previously shown. There is little question that the unit will continue to show good results as the design overflow rate is approached by increasing sewage flows.

The data presented cannot demonstrate the peculiar feature of the Vacuator which perhaps prompted its selection for Palo Alto. That feature is its ability to foster scum formation within the unit, where it can be handled, rather than on the clarifier surface, where it cannot be handled. This ability can be demonstrated, however, by the accompanying photographs of the scum conditions on the Palo Alto clarifier. Figure 5 illustrates conditions prevailing during the canning season before the war. Figure 6 is typical of what happened during the 1948 canning season when the Vacuator was shut down or otherwise inoperative. When the unit was operating the clarifier nor-

FIGURE 5.—Scum on clarifier during prewar canning season.

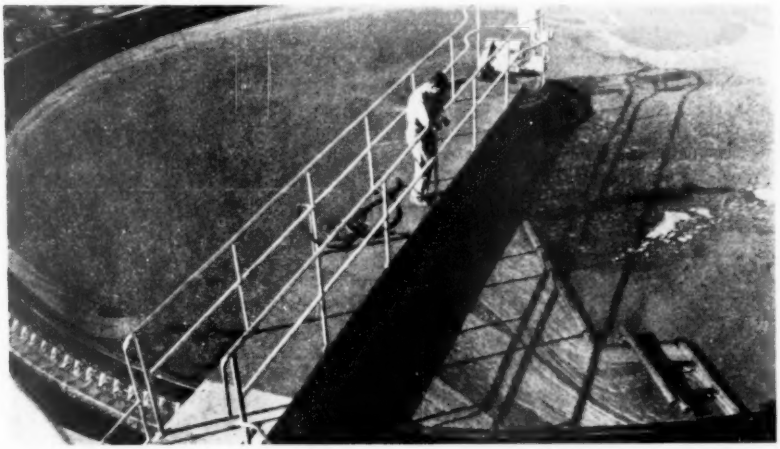

FIGURE 6.—Clarifier during 1948 canning season with Vacuator out of service.

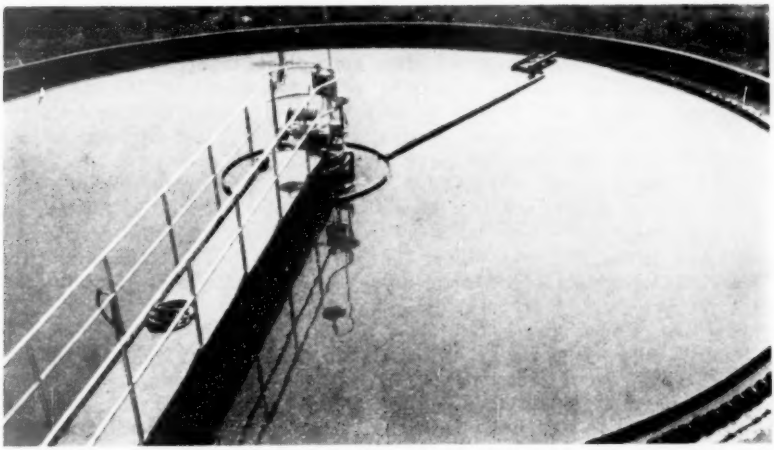

FIGURE 7.—Clarifier during 1948 canning season with Vacuator in service.

mally was entirely free of scum, as shown in Figure 7. These photographs demonstrate far more forcibly than data the feature of the Vacuator which makes it so valuable for treating cannery wastes at municipal sewage treatment plants.

The character of the scum and sludge produced by the unit is of interest. Table II shows average results obtained with several of the wastes studied. The characteristics of the scum and sludge are very similar as far as volatile matter is concerned, indicating that the scum is more than merely the greasy materials of the sewage; it is a representative portion of the suspended solids contained in the sewage.

On the average more than 60 per cent of the solids removed by the unit

were removed as scum; on occasion, this removal increased to 80 per cent. This is of interest because a definite control of the solids content of the scum exists. By increasing the speed of the skimming apparatus, scum with a lower solids content may be obtained; by decreasing the speed, the solids content is increased.

TABLE II.—Characteristics of Scum and Sludge Removed by Vacuator at Palo Alto

Type of Waste	Scum		Sludge	
	Solids (%)	Vol. Matter (%)	Solids (%)	Vol. Matter (%)
Domestic sewage	4.16	81.9	4.89	80.1
Domestic sewage and apricot	5.31	77.6	5.69	78.6
Domestic sewage and peach and pear	4.66	83.3	2.70	79.3

Conclusions

The Palo Alto Vacuator, serving as a primary unit, averaged more than 40 per cent removal of the suspended solids of mixed sewage and cannery wastes, the removal being 48 per cent with domestic sewage alone. From 55 to 60 per cent of the settleable solids by weight were removed. These results indicate that the Vacuator may approach the efficiencies of sedimentation tanks.

Scum formation on the clarifier surface, previously most objectionable, was completely controlled.

Acknowledgment

Grateful acknowledgment for their cooperation and assistance in conducting these tests is made to Harry N. Jenks, consulting engineer; Fabian Miller, city engineer; Harold May, deputy city engineer; Ludwig Huebner, plant superintendent; and the plant personnel.

SLUDGE DISPOSAL STUDY AT HOUSTON, TEXAS*

By J. G. Turney

Consulting Engineer, Houston, Texas

Manufacture of fertilizer from the sludge produced at the city's sewage treatment plants is the function of a sludge disposal plant soon to be placed under construction at Houston, Texas. Bids already have been received and contracts awarded for all mechanical equipment and the main buildings. The project is the result of a study of the sewage sludge disposal problem made for the city in 1947 by Greeley and Hansen, consulting engineers of Chicago, and the writer.

Bonds were voted by Houston in 1941, 1944, and 1946 to provide for a construction program costing approximately $99,000,000. Included in the total was $19,900,000 for construction of sewage treatment plants, pumping plants, sludge disposal plants, and necessary sanitary sewers. Little work was done on this program during the war years, but as materials were made available near the end of the war the program was started and gradually speeded up, particularly through 1945, 1946, and 1947. As a result considerable work has been done on this program, the main part to date being the construction and placing in operation of the Simms Bayou sewage treatment plant in the City of Houston, which made possible the abandonment of several small and inadequate plants built many years ago.

Present Facilities

Houston has in operation three sewage treatment plants, known locally as the North Side, the Simms Bayou and the Magnolia Park plants. Both the North Side and the Simms Bayou plants are of the activated sludge type. The Magnolia Park plant, which is an old, over-loaded Imhoff plant with filter bed, will be abandoned later and its flow diverted to the North Side plant. The degree of treatment at this plant is very poor. The North Side treatment plant is now being enlarged, and the Simms Bayou treatment plant was placed in operation during 1948.

The enlarged North Side treatment plant and the Simms Bayou treatment plant, when all work is completed, will have a combined average flow capacity of 56 m.g.d. The study covered the necessary plant or plants for the city until 1970, with an estimated tributary population at that time of 776,000. It was estimated that at that time the average flow would be 68 m.g.d.

Based on experience of the Houston Public Works Department, it was found that the sewage at the North Side plant would have approximately 303 p.p.m. suspended solids, and that the Simms Bayou plant would have 238 p.p.m. Also, that the sewage at the North Side plant would have 0.22 pounds suspended solids per 24 hours per capita; the Simms Bayou plant, 0.175 pounds per 24 hours per capita. Based on these basic data, it was determined that the average annual quantity of dry solids for the year 1970 would be 71 tons per 24 hours.

Project Descriptions

On this basis several projects were studied and estimates of their cost prepared. Six of the projects are on raw sludge; five, for digested sludge.

Project 1R provides for pumping raw activated sludge from the North Side plant to the Simms Bayou plant, where a single dewatering plant would

* Presented at Thirty-first Texas Water and Sewage Works Short School; College Station, Tex.; Feb. 6–10, 1949.

be constructed for vacuum filtration of sludge from both plants. The sludge cake produced would be hauled to a disposal area located east of the city.

Project 2R provides for pumping combined raw preliminary and excess activated sludge from the Simms Bayou plant to the North Side plant, where a single dewatering and drying plant would be constructed for the manufacture of fertilizer.

Project 3R provides for pumping combined raw preliminary and excess activated sludge from the Simms Bayou plant to the North Side plant, where a single dewatering and incineration plant would be constructed. Ash from the incineration process would be hauled to a disposal area east of the city.

Project 4R provides for pumping raw sludge from the North Side and Simms Bayou plants to lagoons constructed on a tract of land east of the city, with necessary facilities for handling sludge as delivered to the lagoon site.

Project 5R provides for constructing raw sludge storage tanks and barge loading docks at the North Side and Simms Bayou plants, and hauling raw sludge in rented barges and tugs to a point in the Gulf of Mexico about 40 miles off the Galveston jetties, or a total one-way trip of about 90 miles from Houston.

Project 6R is similar to Project 2R, except that the existing sludge lagoons at the North Side plant would be used to their capacity. This would somewhat reduce the yearly average quantity of sludge to be handled by the sludge dewatering and drying plant, and eliminate equipment to take care of the peak rates of sludge production. No spare equipment for standby service would be included.

Projects 1D to 5D are similar to Projects 1R to 5R, inclusive, except that they are on the basis of digested sludges.

Estimated total construction costs and estimated net total annual costs for the several projects are shown in Table I. The estimated net total annual cost is the sum of annual operating costs and debt service, less the revenue received from the sale of fertilizer, which is available only in Projects 2R, 6R, and 2D.

TABLE I.—Estimated Costs of Houston Sludge Disposal Projects Studied

Project	Total Construction Cost ($)	Net Total Annual Cost ($)
1R	$1,237,000	$268,060
2R	2,078,000	83,330
3R	2,158,000	367,120
4R	985,000	100,550
5R	984,000	443,960
6R	1,394,000	57,420
1D	$3,172,000	$355,830
2D	3,869,000	295,300
3D	3,921,000	397,420
4D	2,906,000	227,240
5D	2,620,000	249,030

Recommended Project

Based on these estimates of cost for construction and annual cost, considering the revenue received from the sale of fertilizer, it was recommended that Project 6R be adopted and planned. This project, estimated to cost $1,394,000, would provide for mechanical dewatering and heat drying of all sludge produced by the two plants through the year 1960, except for peak loads and emergencies. After 1960 it will be necessary to utilize the lagoons, it being planned that approximately 10 tons of dry solids per 24 hours will be placed in lagoons and that dewatering and drying equipment will handle 61 tons per 24 hours.

The project includes the following major structures and equipment:

A raw sludge pumping station at the Simms Bayou plant.

An 8-in. sludge force main approximately 36,000 ft. long from the Simms Bayou plant to the North Side plant.

A sludge dewatering plant at the North Side sewage treatment plant, equipped with 4 vacuum filters of 570

sq. ft. each, to reduce the moisture content of the sludge from 98.5 per cent to 80 per cent.

A drying plant with two flash driers, each having a capacity to evaporate at least 12,000 lb. of water per hour, together with necessary conveyors, screens, and grinders, for preparing and handling the sludge as fertilizer, and a storage space with steel bins and necessary conveyors and elevators capable of storing approximately 1,000 tons of dried material (6 per cent moisture).

The adopted project is estimated to cost $1,394,000, with an annual operating cost of $261,020 per year, and debt service of $64,400 per year, making a total annual cost of $325,420. Anticipated revenue of $268,000 per year is based on the sale of 21,000 tons of fertilizer yearly at an average bulk sale price of $12.25 per ton. This price for the dried material is considered conservative, and is somewhat below the average sale price of past years. There was, however, no complete assurance that sludge sales in the amount estimated could be realized, but insofar as careful predictions could be made, the estimated total annual revenue is considered to be reasonable.

The advantage of the chosen project over that having the next lower cost results from the sale of fertilizer. The income, therefore, depends on marketing this commodity at a favorable price. The cost of processing includes considerable labor and costs for chemicals, repairs, and other items.

The estimates were conservatively made on the basis of experience in Houston and elsewhere, and careful inquiry into the possibilities of marketing fertilizer. It is realized, however, that future economic conditions could change the relationship between cost and revenue. It was recommended that if the City of Houston was prepared to enter the business of manufacturing and selling fertilizer in large quantities, that method of sludge disposal was considered the most favorable. Nevertheless, the recommended project has the further advantage of completely disposing of the material, and at best lagooning would be somewhat of a nuisance, regardless of how carefully operated.

It might be well to comment briefly on the estimated revenue to be derived from this plant. It is estimated that 21,000 tons of material will be produced yearly and that this material can be sold at $12.25 per ton. The city at this time is selling fertilizer at approximately $17.25 per ton. If it were possible to produce the material at the estimated rate and sell it at present cost, the city could definitely show a profit. The project, based on 90 per cent removal of the solids in the sewage, will result in a net cost to the city of $2.60 per ton of disposal for all solids reaching the plants. It appears that there is, within a reasonable distance from Houston, a stable market for all of the fertilizer that can be produced by the city.

Ferric Sulphate Conditioner

Subsequent to the adoption of the study and approval of the recommended project, detailed plans and specifications were prepared, bids were received, and contracts were awarded for the dewatering equipment and the drying equipment. The cost of the dewatering equipment (for delivery and erection in 370 calendar days) is $144,670, and includes furnishing and installing the filters and conditioning equipment, together with all their auxiliaries. It is planned to use ferric sulphate as the conditioner, although the chemical handling and storage room is designed to use almost any kind of conditioner known. Ferric sulphate, used in Houston's old disposal plant, is the lowest cost conditioner available to the city at this time. It appears, however, that other conditioners may be made available in the not too distant

future, and if proved satisfactory will no doubt be adopted for use.

The contract for the drying units provides for furnishing two flash-type drying units and their appurtenances, each having a capacity to evaporate not less than 12,000 lb. of water per hour. Based on delivery in 490 calendar days, the cost will be $376,220. This equipment will be installed in a new building with steel frame and corrugated asbestos roof and siding, located immediately north of the existing Hu-Actinite plant at the North Side sewage treatment plant.

Included in the next contract are the new building and the foundations for the equipment and stack. Bids will be received soon for the sludge storage tank, piping, wiring, and the installation of storage bins and handling equipment in the existing fertilizer building.

The plant is laid out so that it can be expanded on city owned land to twice its installed capacity. If further expansion is required it might be more economical to construct another plant, depending entirely on the need for additional treatment facilities. With the proposed expansion of the city, another treatment plant located in the northeastern part of the city seems to be indicated, and it will probably prove economical to construct an additional sludge disposal plant at that location, rather than to concentrate all of the sludge disposal work at one location. However, the layout of the new plant is such that it can be expanded to dispose of sewage sludge from a city having a population of 1,500,000. Present plans call for the new sludge disposal plant for the City of Houston to be completed and in operation by June, 1950.

FIFTH INDUSTRIAL WASTE CONFERENCE

The Fifth Industrial Waste Conference, scheduled to be held at Purdue University, Lafayette, Indiana, on November 29–30, 1949, is being planned to cover the developments in waste disposal and utilization. In addition to a number of papers on such miscellaneous subjects as changes in laws and regulations, stream qualities, and stream surveys, there will be separate sessions on particular subjects such as food processing wastes, dairy wastes, metal wastes, laboratory procedures, and conservation of resources.

Sponsored by the Civil Engineering Department of Purdue University, and cooperating agencies, the Industrial Waste Conferences of past years have been noteworthy for the high calibre and timeliness of the papers presented and the discussions provoked. As in former years, Don E. Bloodgood, professor of sanitary engineering at Purdue University, is chairman of the conference.

EFFECT OF CERTAIN PHYSICAL AND CHEMICAL AGENTS ON THE BACTERIA AND PROTOZOA OF ACTIVATED SLUDGE *

By H. Heukelekian and M. Gurbaxani

The relative roles played by bacteria (zoogleal types) and protozoa in the activated sludge process have been the subject of experimentation and discussion for a number of years. That pure cultures of zoogleal organisms can purify sewage without the aid of any other organisms was shown by Butterfield (1). The removal of oxidizable material by aeration with a pure culture zoogleal sludge for a 3-hr. period varied from 41 to 71 per cent. Upon aeration with a pure culture of zoogleal sludge containing *Colpidium* a higher removal of oxidizable material was obtained (84 per cent) than by the aeration with zoogleal sludge without the *Colpidium* (64 per cent). It was observed that the supernatant from a mixture containing *Colpidium* was much clearer.

Experiments conducted later by workers in the Cincinnati Stream Pollution Laboratories (2) amplified the early findings of Butterfield. Over-all purification varying from 80 to 90 per cent, as measured by B.O.D. removal, was obtained with aeration for 6 hr. with pure culture zoogleal sludge. It was reported that normal crude culture activated sludge does not have as great a capacity for removing colloidal or soluble organic matter as does the pure culture. Despite this unusual observation regarding the superiority of pure culture sludge over crude activated sludge, it was concluded that a remarkable similarity exists between the purification accomplished by both pure culture and normal activated sludges.

Heukelekian and Littman (3) were also able to produce flocculent masses of activated sludge from pure cultures of *Zoogloea ramigera*, which were able to reduce the B.O.D. of the treated sewage 60 to 90 per cent. These pure culture sludges simulated activated sludge and exerted the same clarifying and purifying action on the sewage.

From the foregoing evidence it can be concluded that pure culture zoogleal sludges can purify sewage without the assistance of protozoa at about the same rate as natural activated sludge containing a mixed flora and fauna. There is also some evidence that the presence of protozoa, such as *Colpidium*, results in a somewhat higher removal of B.O.D.

Cramer (4) recognized the importance of bacteria, as well as protozoa, in the clarification of sewage by the activated sludge process. Pillai and Subrahmanyan (5) reported that they were able to get at least as active purification of sewage with pure cultures (bacteria free) of *Epistylis sp.* as with the normal activated sludge. They stated that conditions affecting the life and activity of the protozoa also affect the efficiency of purification. When protozoa were killed or inactivated by heating at 50° C., sludge formation and clarification were nil; whenever purification was proceeding satisfactorily protozoa were active. They concluded that aerobic purification of sewage was essentially due to the protozoan activity and that bacteria play only a secondary part. Pillai, Wadhwani, Gurbaxani, and Subrahmanyan

* Paper of the Journal Series, N. J. Agricultural Experiment Station, Department of Sanitation, Rutgers University, New Brunswick, N. J.

(2) in a comparison of various bacteria and two protozoa, *Vorticella sp.* and *Epistylis sp.*, found that protozoa were more active than bacteria in the flocculation and oxidation of the organic matter in sewage.

Thus, there is considerable divergence of views regarding the role played by bacteria and protozoa in the activated sludge process. The views may be summed up as follows: 1) Bacteria can bring about purification without the assistance of protozoa, but when the latter are present a better B.O.D. removal is obtained; 2) Both bacteria and protozoa are important; and 3) Protozoa are the important agents responsible for purification, and bacteria play only a secondary part.

Because of these divergent views, it was considered of interest to study the relative importance of bacteria and protozoa in the activated sludge process. The objective was to destroy the protozoa without affecting the bacteria and to determine the effect on the purification of sewage by the activated sludge process.

Experimental Methods

Both physical and chemical means of destroying the protozoa were tried. After the activated sludge was pretreated by various means it was mixed with heat-sterilized sewage and aerated for 16 to 20 hr. Microscopic examinations were made to determine the activity of the protozoa in the untreated and the pretreated sludges and in sludges after mixture with sewage and after aeration of the mixtures. Bacterial numbers of the sludge and of the mixtures of sludge with sewage before and after aeration were determined after mixing and dispersing in a Waring blender for 10 min. Cool water was circulated through coils immersed in the sludge to prevent temperature rise during blending. The amount of purification was measured by determining B.O.D. and turbidity of the supernatant before and after settling.

Results of Experiments

The activity of the protozoa in the dispersed sludge was observed under the microscope and the total numbers of bacteria in the original sludge and in the dispersed sludge were determined (Table I). As expected, dispersion of the activated sludge increased the numbers of bacteria. Rapid mixing inactivated and probably killed the ciliated protozoa, as indicated by a thorough microscopic examination. The sharp difference in behavior of the two groups of organisms resulting from such a simple physical method offered an approach to the problem of the role played by protozoa in the purification of sewage by the activated sludge process. Rapid mixing of the activated sludge in the blender prior to aeration with sewage caused the sludge to break up and increased the turbidity of the sludge liquor. To eliminate this initial increase in the turbidity due to the pretreatment of the sludge and to differentiate it from the effect of mixing on the protozoa in the subsequent purification of sewage when admixed with the treated sludge, the activated sludge was washed twice and centrifuged to remove the dispersed particles in suspension. The results of a typical experiment are given in Table II. Dispersion of the sludge by rapid mixing, which inactivated the protozoa, gave also, on aeration with sewage, a supernatant liquor of higher turbidity and B.O.D. than the untreated sludge control. Purification was accomplished when the protozoa were inactivated by rapid mixing, although the supernatant liquor of the sludge pretreated in

TABLE I.—Effect of Dispersion of Activated Sludge on the Protozoa and Bacteria

Sludge Condition	Condition of Protozoa	Total Bacterial Count (1,000 ml.)
Dispersed	Inactive	62,000
Undispersed	Active	7,000

TABLE II.—Effect of Dispersion of Activated Sludge on the Purification of Sewage After Aeration

Item	Dispersed Sludge		Undispersed Sludge	
	Before Aeration	After Aeration	Before Aeration	After Aeration
Condition of protozoa	Inactive	Inactive	Active	Active
Turbidity (p.p.m.)	320	40	140	<20
B.O.D. (p.p.m.)	350	35	140	5

this way had a B.O.D. and turbidity higher than that obtained by the untreated sludge.

Heating as a method of inactivating the protozoa was suggested by Pillai and Subrahmanyan (5). They found that heating activated sludge to 50° C. not only killed the protozoa, but also stopped clarification of sewage by activated sludge. The results of an experiment in preheating the sludge to 50° C. for 5 min., mixing with sewage, and aerating are given in Table III. Heating resulted in a great increase in the numbers of bacteria after aeration, whereas the numbers in the unheated sludge remained at about the same level after aeration. The protozoa were completely inactivated by heating; clarification, as measured by turbidity, was inhibited. In comparison with the control, B.O.D. removal was impaired by heating, but was not completely stopped.

Freezing of the sludge was also attempted as a means of inactivating the protozoa. Table IV gives the results of such an experiment. Freezing inactivated the protozoa and impaired turbidity and B.O.D. removals.

Methylene blue was selected as a chemical means of selectively killing the protozoa, on the basis of the findings of Pillai and Subrahmanyan (5). In a preliminary study various concentrations of methylene blue were added to activated sludge to determine the dosage suitable for killing the protozoa without affecting the bacteria. The results (Table V) show that it was not possible completely to inactivate the protozoa with even 500 p.p.m. of the dye. At this concentration, the bacterial numbers were greatly reduced. In passing, it may be of interest to note that the lowest concentration of methylene blue used (1.35 p.p.m.), which is the same concentration as that used in the relative stability test, had little effect on the bacterial numbers of the sludge. When this concentration of dye was added to sewage dilutions and incubated it was found that the oxygen

TABLE III.—Effect of Heat-Treated Activated Sludge on Protozoa and Bacteria, and on the Clarification of Sewage by Aeration

	Heated to 50° C. in 5 min.		Not Heated	
	Before Aeration	After Aeration	Before Aeration	After Aeration
Total bacteria (1,000/ml.)	16	12,500	16	18
Condition of protozoa	Inactive	Inactive	Active	Active
Turbidity (p.p.m.)	64	55	47	20
B.O.D. (p.p.m.)	63	22	51	1

TABLE IV.—Effect of Freezing of Activated Sludge on the Protozoa and on the Purification of Sewage by Aeration

	Frozen		Not Frozen	
	Before Aeration	After Aeration	Before Aeration	After Aeration
Condition of protozoa	Inactive	Some active	Active	Active
Turbidity (p.p.m.)	47	30	45	<20
B.O.D. (p.p.m.)	65	24	58	6

TABLE V.—Effect of Methylene Blue on the Bacteria and Protozoa of Activated Sludge

Dye Concentration (p.p.m.)	Condition of Protozoa	Total Bacteria (1,000/ml.)
0	Active	1,600
1.35	Active	1,500
20	Many active	850
200	Some active	12
500	Few active	1

TABLE VI.—Effect of Silver-Treated Activated Sludge on Bacteria and Protozoa in Activated Sludge and on Purification of Sewage after Aeration

Total	Silver-Treated[1]		Not Treated	
	Before Aeration	After Aeration	Before Aeration	After Aeration
Bacteria (1,000/ml.)	80	36,000	2,400	5,500
Condition of protozoa	Inactive	Inactive	Active	Active
Turbidity (p.p.m.)	185	120	180	20
B.O.D. (p.p.m.)	100	40	70	7

[1] 4 p.p.m.

utilization rate (B.O.D.) up to 5 days was not affected. It is of interest to note that Abbott (6) added 3 p.p.m. methylene blue to B.O.D. dilutions to suppress nitrification, and that during the carbonaceous stage the B.O.D. values were not affected by the addition of the dye.

Despite the unsatisfactory results obtained with methylene blue in selective killing, an experiment was run with the addition of 200 p.p.m. of the dye to the activated sludge, followed by aeration with sewage for 16 hr. It was found that in the presence of the dye the protozoa were inactive at the end of the aeration period. The bacteria in the sludge, although decreased initially, at the end of the aeration period had attained a population level equal to that of the control after a similar aeration period. The purification, however, as measured by the B.O.D. and turbidity of the supernatant liquor after aeration, was impaired, whereas in the control it was normal.

Treatment of the activated sludge with silver was tried as a means of partial sterilization. A current of 35 to 135 milliamperes at 6 volts was passed through silver electrodes. The silver put in solution was calculated from the electrochemical equivalent of silver, the current, and the time. The treated and untreated sludges were mixed with sewage and aerated for 20 hr. The results (Table VI) show that treatment of the sludge with silver decreased the numbers of bacteria initially, but that after the aeration period the numbers exceeded those in the untreated sludge. It also inactivated the protozoa and affected turbidity and B.O.D. removals.

It has been shown (7) that chlorination of the activated sludge to a residual kills the protozoa and increases the B.O.D. of the effluent by deflocculating the sludge. Rudolfs and Lacy (8) have shown that even partial chlorination of the sludge produces a poorer effluent. Chlorination of activated sludge for the purpose of controlling bulking came into vogue later, with similar observations that it increased the turbidity of the effluent. The extent of increase in turbidity is dependent on the quantity of chlorine used. Additional experiments (Table VII) show that chlorine, when applied in a 5-p.p.m. concentration, decreases the bacterial numbers initially, but increases the numbers greatly after

TABLE VII.—Effect of Chlorine Treatment of Activated Sludge on the Bacteria, and Protozoa, and on the Purification of Sewage After Aeration (18 hours)

	Treated with Chlorine				Not Treated	
	5 p.p.m.		20 p.p.m.		Before Aeration	After Aeration
	Before Aeration	After Aeration	Before Aeration	After Aeration		
Bacteria (1000/ml.)	16	150,000	0.5	1,500	40,000	120,000
Condition of protozoa	Active	Inactive	Active	Inactive	Active	Active
Turbidity (p.p.m.)	45	32	45	62	45	20
B.O.D. (p.p.m.)	67	15	75	68	70	12

TABLE VIII.—Comparison of Purifying Capacity of Natural, Zoogleal, and Zoogleal-Protozoan Activated Sludges on Sewage

Type of Sludge	Susp. Sol. in Mixed Liquor (p.p.m.)	Aeration Period (hr.)				
		1	2	3	4	24
		B.O.D. Reduction (%)				
Natural activated	1,850	80	81	81	85	85
Zoogleal, Z-1	1,347	56	87	90	75	75
Zoogleal-protozoan	1,425	52	67	70	87	88
		Turbidity Reduction (%)				
Natural activated	1,850	54	90	90	85	69
Zoogleal, Z-1	1,347	57	63	70	68	42
Zoogleal-protozoan	1,425	39	60	76	92	87

the aeration period. Chlorine inactivates the protozoa and impairs the turbidity and B.O.D. removals. With a 20-p.p.m. dosage, the effect on the initial decrease of bacteria is greater, the subsequent recovery of numbers is not so great, and the deterioration in the quality of the effluent is greater than with the 5-p.p.m. dosage.

Additional information can be obtained regarding the role played by protozoa in the activated sludge process without treating the sludge physically or chemically, but by comparison of the rates of purification of natural activated sludge, pure culture zoogleal sludge, and zoogleal sludge to which cultures of protozoa are added. *Paramecium*, which was cultivated and demonstrated to be bacteria free, was added in great numbers (28,000 per ml. of mixed sludge) to pure culture zoogleal sludge. The various types of sludges were mixed with heat sterilized sewage and aerated. The B.O.D. and turbidity removals after various periods of aeration are given in Table VIII. The natural activated sludge with its balanced flora and fauna gave the maximum rate of B.O.D. and turbidity removals. With protozoa-free pure culture zoogleal sludge high rates of B.O.D. removal can also be obtained, but turbidity removal is lower than with natural activated sludge. In the presence of protozoa the B.O.D. removals by the zoogleal sludge were no higher than in the absence of protozoa, but turbidity removals were higher.

Discussion

The observation that high speed mechanical agitation inactivates protozoa is of interest. It is not possible to state whether the organisms actually were killed. However, microscopic observation after violent agitation in a Waring blender failed to show any movement of the cells or the cilia, whereas before the treatment the organisms in the sludge were active. Inasmuch as activity failed to develop after prolonged periods of aeration in the presence of sewage, it is fair to presume that the organisms were killed. Cultural methods are required to establish this point definitely. The increase in bacterial numbers by agitation is merely the physical effect of dispersion of bacterial aggregates and can be utilized for better enumeration of the bacterial numbers of such aggregates. Even after mechanical agitation it is doubtful whether the total number of bacteria in the activated sludge floc is actually obtained.

The evidence presented with the various physical and chemical methods

of selective killing of protozoa in the activated sludge indicates that clarification and B.O.D. removal after aeration with sewage are impaired but not completely inhibited. Mechanical agitation, heating, freezing, silver, and chlorine all inactivate the protozoa. Contrary to the results recorded by Pillai and Subrahmanyan, complete inactivation of protozoa by methylene blue required high concentrations of the dye. This also reduced the bacterial numbers greatly. Partial sterilization by heating the sludge to 50° C. impaired clarification more or less completely, which is in agreement with their findings. However, B.O.D. removals were affected to a lesser extent. Other methods that also resulted in inactivation of protozoa, such as freezing and mechanical dispersion, affected clarification only partially.

The effect of either physical or chemical methods of treatment on the physical state of the sludge floc, in addition to their effect on protozoa, should be kept in mind. The evidence presented here, as well as that given by others, shows that protozoa assist in the clarification of the effluent, giving a more highly polished effluent, but are by no means essential to biochemical oxidation. The repeated successful purification obtained by the various investigators cited with pure culture zoogleal sludges is sufficient proof of this. Protozoa appear to be an aid in purification, but are of secondary importance to bacteria.

Summary

1. High speed mechanical agitation of activated sludge inactivates the protozoa and causes an apparent increase in the numbers of bacteria by dispersing the aggregates.

2. Heating the sludge to 50° C. also inactivates the protozoa and causes an initial decrease in the bacterial numbers of the sludge, but upon aeration with sewage the bacterial numbers increase whereas the protozoa remain inactive.

3. Freezing of the sludge inactivates the protozoa.

4. Methylene blue in high concentrations inactivates protozoa and reduces bacterial numbers.

5. Treatment of activated sludge with silver and chlorine reduces the bacterial numbers and inactivates the protozoa. Upon aeration with sewage, bacterial numbers increase but protozoa remain inactive.

6. Purification was obtained when the protozoa were inactivated by physical and chemical methods of partial sterilization, but the degree of purification was impaired. Clarification was affected to a greater degree than was B.O.D. removal.

7. Protozoa-free pure culture zoogleal sludge can purify sewage, but turbidity removal is not so high as is B.O.D. removal.

8. Protozoa assist in clarification and appear to aid purification, but are of secondary importance to bacteria.

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STATES EXPAND CONSERVATION ACTIVITY

Increasing awareness of the importance of pollution abatement and conservation of natural resources is indicated by state legislative action in 1949 sessions. In some cases, as noted recently by the American Society of Planning Officials, expanded conservation activities involved new approaches in interstate cooperation.

In addition to the revamping of the Michigan pollution abatement agency (see p. 839), the following actions have been taken thus far this year:

Nevada provided for cooperative agreements with surrounding states concerning natural resources, and created a special committee to work with California in dealing with the problems of the Lake Tahoe area.

Colorado and Utah ratified the Upper Colorado River Compact, as all the other Colorado basin states have done. Rhode Island ratified the proposed New England Development Authority Compact; Vermont, the New England Water Pollution Control pact.

In Arkansas, the General Assembly adopted a broad program for stream pollution control and approved an expanded game and fish development program. Idaho provided appropriations to develop lands for watershed protection and recreational use.

The Tennessee legislature gave conditional approval to the Ohio River Valley sanitation compact already in effect among 8 states. It also created a fish and game commission, a stream pollution control study commission, and a new advisory conservation commission.

Both Montana and Nevada enacted water pollution control acts and legislation on construction and financing of sewerage facilities. New York approved a law to establish a state-wide program for control of pollution in streams and marine waters.

THE EFFECT OF SEA WATER ON THE BIO-CHEMICAL OXIDATION OF SEWAGE *

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The biochemical oxidation of sewage in brackish waters such as the ocean, estuaries, harbors, and tidal basins has been studied by Adeney (1) (2), Purvis and associates (3) (4) (5) (6) (7), Letts and Richards (8), Clark (9) (10), and Baity (11) (12). In some cases the results of these studies are in conflict as to the effect of sea water on (1) the rate of oxidation during the first stage, (2) the magnitude of the first stage, (3) the lag period, and (4) the second stage of oxidation or nitrification.

The objectives of this investigation are to obtain further information on the subject and to determine which of the conflicting results of the previous experiments can be corroborated.

Experimental Procedure

Six series of experiments (A, B, C, D, E, and F) were made, using various percentage mixtures of sea water and sodium bicarbonate for the dilution of the sewage. The excess oxygen method for determining B.O.D. was used throughout the investigation. The sodium bicarbonate and phosphate dilution waters were prepared as recommended in "Standard Methods" (13). The sodium azide modification of the Winkler method, as described by Ruchhoft (14) was used for the dissolved oxygen determinations. Mixtures of sewage dilution water and acclimated seeding material were siphoned into ground glass stoppered bottles, and incubated under water at the designated temperature.

The seeding material was prepared by mixing sewage and polluted sea water with the specific dilution water mixture with which it was to be later used. The concentrations were such that the dissolved oxygen was not depleted during the period of incubation and acclimatization, which was at least 15 days. Other procedures followed in carrying out the experiments are the same as previously described by the writer (15).

The four groups of experiments of Series A (Table I) were incubated at 5° C., 10° C., 15° C., and 20° C., respectively, and contained 1.48 per cent of Cambridge, Mass., raw sewage filtered through cotton, and 0.98 per cent of acclimated seed. The dilution waters for each group were: (1) sodium bicarbonate water; (2) a mixture of two-thirds sodium bicarbonate and one-third sea water (chlorides concentration 6,100 p.p.m.); (3) a mixture of one-third sodium bicarbonate water and two-thirds sea water (chlorides concentration 12,200 p.p.m.); and (4) straight sea water (chlorides concentration 18,300 p.p.m.)

The dilution waters used in Series B, C, D, E, and F (Table II) were: (1) sodium bicarbonate water; (2) phosphate buffered water; (3) 97 per cent bicarbonate and 3 per cent sea water; (4) 91 per cent bicarbonate and 9 per cent sea water; (5) 80 per cent bicarbonate and 20 per cent sea water; (6) 65 per cent bicarbonate and 35 per cent sea water; (7) 50 per cent bicarbonate and 50 per cent sea water; (8) 25 per cent bicarbonate and 75 per cent sea water; and (9) 100 per cent sea water. The chlorides concentra-

* Presented at Twenty-first Annual Meeting, New York State Sewage Works Association; New York City; Jan. 21, 1949.

TABLE I.—Constants for First-Stage B.O.D. (Series A)

Dilution Water	Rate Constant, K			First-Stage B.O.D., L			Lag (days)
	Value	Probable Error		Value (p.p.m.)	Probable Error		
		Actual	%		Actual (p.p.m.)	%	
(a) Incubated at 5° C.							
Bicarbonate	0.06585	±0.00557	± 8.5	238	±25	±10.5	3.22
6,100 p.p.m. Cl	0.06348	±0.00329	± 5.2	254	±17	± 6.7	1.01
12,200 p.p.m. Cl	0.07549	±0.00384	± 5.0	247	±16	± 6.5	0.62
18,300 p.p.m. Cl	0.09771	±0.00374	± 3.8	243	±12	± 4.9	1.04
(b) Incubated at 10° C.							
Bicarbonate	0.08149	±0.00920	±11.3	226	±32	±14.0	0.55
6,100 p.p.m. Cl	0.15098	±0.00530	± 3.5	263	±12	± 4.6	0.54
12,200 p.p.m. Cl	0.13036	±0.00481	± 3.7	235	±11	± 4.7	0.11
18,300 p.p.m. Cl	0.12650	±0.00482	± 3.8	241	±11	± 4.6	0.04
(c) Incubated at 15° C.							
Bicarbonate	0.15513	±0.00794	± 5.1	224	±15	± 6.7	0.56
6,100 p.p.m. Cl	0.17745	±0.00371	± 2.1	252	± 7	± 2.8	0.05
12,200 p.p.m. Cl	0.20254	±0.00322	± 1.6	237	±15	± 6.4	0.00
18,300 p.p.m. Cl	0.19181	±0.00475	± 2.5	247	± 8	± 3.2	−0.01
(d) Incubated at 20° C.							
Bicarbonate	0.17215	±0.00744	± 4.3	230	±13	± 5.7	0.00
6,100 p.p.m. Cl	0.27618	±0.01430	± 5.2	235	±16	± 6.8	−0.07
12,200 p.p.m. Cl	0.28582	±0.02470	± 8.7	236	±20	± 8.5	0.03
18,300 p.p.m. Cl	0.26029	±0.02015	± 7.7	247	±24	± 9.7	−0.03

tions were as shown in Table II. Chapel Hill, N. C., settled sewage filtered through cotton was used in Series B, C, D, E, and F. The dilution factor was determined by making an oxygen consumed from permanganate test on the sewage. The following percentages of sewage and acclimatized seed were used in the experiments: Series B, 1.95 per cent sewage and 0.49 per cent seed; Series C, 2.83 per cent sewage and 2.83 per cent seed; Series D, 1.95 per cent sewage and 0.97 per cent seed. The experiments of Series B, C, and D were incubated at 20° C.; Series E and F, at 10° C.

Experimental Results *

Tables I and II show the computed values of k, the rate constant; L, the ultimate first-stage B.O.D.; the lag period of the first stage; and the probable errors in the values of k and L. The actual B.O.D. observations and the

* A dissertation, "Biochemical Oxidation of Sewage in Fresh and Brackish Waters at Different Temperatures," by H. B. Gotaas, containing the detailed experimental results and a more extensive analysis and study of the information than is feasible to present here, is in the library of Harvard University, Cambridge, Mass., and the library of the University of North Carolina, Chapel Hill, N. C.

comparable B.O.D. values computed from k and L are not shown in tabular form because of the space that would be required. However, Figures 1 to 9, respectively, show graphically the B.O.D. observations and the computed B.O.D. curve of best fit for each series. The observed points and curves of Series B, C, and D were so close together during the first few days that only the upper and lower limits can be shown on the figures. When the magnitudes of the B.O.D.'s for two or more bottles titrated at the same time for a curve were almost the same, it was not possible to plot the individual observations on the figures. Hence, the average of the observations was plotted, but each observation was used in computing the curve of best fit.

To avoid making the published curves unduly long, only observations up to 34 days are shown. The observations for some of the curves at 10°

TABLE II.—Constants for First-Stage B.O.D. (Series B, C, D, E, and F)

Dilution Water	Rate Constant, k			First-Stage B.O.D., L			Lag (days)
	Value	Probable Error		Value (p.p.m.)	Probable Error		
		Actual	%		Actual (p.p.m.)	%	
(a) Series B, Incubated at 20° C.							
Bicarbonate	0.16117	±0.00769	± 4.8	138	± 8	± 5.8	−0.01
Phosphate	0.17703	±0.00608	± 3.4	144	± 6	± 4.2	−0.16
550 p.p.m. Cl	0.21327	±0.01800	± 8.5	137	±12	± 8.8	0.07
1,650 p.p.m. Cl	0.19207	±0.00588	± 3.1	141	± 4	± 2.8	−0.01
3,650 p.p.m. Cl	0.17730	±0.00432	± 2.4	137	± 5	± 3.7	−0.18
6,400 p.p.m. Cl	0.16232	±0.00990	± 6.1	149	± 9	± 6.0	0.03
9,100 p.p.m. Cl	0.16084	±0.00617	± 3.8	146	± 7	± 4.8	0.27
13,650 p.p.m. Cl	0.14479	±0.00797	± 5.5	150	± 8	± 5.3	0.18
18,250 p.p.m. Cl	0.13729	±0.00537	± 3.9	150	± 7	± 4.7	−0.04
(b) Series C, Incubated at 20° C.							
Bicarbonate	0.15970	±0.00429	± 2.7	358	±11	± 3.1	0.01
Phosphate	0.18047	±0.00515	± 2.8	303	±12	± 4.0	0.06
550 p.p.m. Cl	0.16801	±0.00408	± 2.4	338	±10	± 3.0	0.07
1,650 p.p.m. Cl	0.19418	±0.00163	± 0.8	331	± 3	± 0.9	0.03
3,650 p.p.m. Cl	0.19780	±0.00388	± 2.0	326	± 8	± 2.5	0.09
6,400 p.p.m. Cl	0.17141	±0.00284	± 1.7	310	± 6	± 1.9	0.03
9,100 p.p.m. Cl	0.17381	±0.00248	± 1.4	297	± 5	± 1.7	−0.03
13,700 p.p.m. Cl	0.13540	±0.00837	± 6.2	318	±23	± 7.2	−0.29
18,300 p.p.m. Cl	0.12620	±0.00892	± 7.1	368	±30	± 8.1	−0.50
(c) Series D, Incubated at 20° C.							
Bicarbonate	0.18718	±0.00257	± 1.4	236	± 4	± 1.7	0.06
Phosphate	0.20517	±0.00648	± 3.1	217	± 9	± 4.1	−0.03
550 p.p.m. Cl	0.20230	±0.00177	± 2.4	272	± 8	± 2.9	0.00
1,650 p.p.m. Cl	0.20814	±0.00643	± 3.1	240	±17	± 7.1	−0.01
3,650 p.p.m. Cl	0.23042	±0.00336	± 1.5	250	± 5	± 2.0	0.05
6,400 p.p.m. Cl	0.17668	±0.00375	± 2.1	243	± 5	± 2.1	−0.02
9,200 p.p.m. Cl	0.17435	±0.00411	± 2.3	215	± 6	± 2.8	0.02
13,750 p.p.m. Cl	0.16490	±0.00725	± 4.4	236	±13	± 5.5	0.01
18,350 p.p.m. Cl	0.13670	±0.00205	± 1.5	242	± 4	± 1.7	−0.15

TABLE II.—*Continued*

Dilution Water	Rate Constant, K			First-Stage B.O.D., L			Lag (days)
	Value	Probable Error		Value (p.p.m.)	Probable Error		
		Actual	%		Actual (p.p.m.)	%	
(d) Series E, Incubated at 10° C.							
Bicarbonate	0.06412	±0.00516	± 8.1	230	±22	± 9.6	0.70
Phosphate	0.07075	±0.00605	± 8.6	239	±25	±10.5	1.08
550 p.p.m. Cl	0.09283	±0.00230	± 2.5	240	± 8	± 3.3	−0.02
1,650 p.p.m. Cl	0.07137	±0.00380	± 5.3	252	±16	± 6.3	−0.35
3,650 p.p.m. Cl	0.07438	±0.00165	± 2.2	262	±10	± 3.8	−0.12
6,400 p.p.m. Cl	0.07209	±0.00291	± 4.0	274	±14	± 5.1	−0.25
13,750 p.p.m. Cl	0.07083	±0.00275	± 3.9	323	±15	± 4.7	−0.015
18,350 p.p.m. Cl	0.06847	±0.00341	± 5.0	365	±20	± 5.5	−0.010
(e) Series F, Incubated at 10° C.							
Bicarbonate	0.12282	±0.00671	± 5.5	146	± 6	± 4.1	0.19
Phosphate	0.18529	±0.01080	± 5.8	123	± 9	± 7.3	0.41
550 p.p.m. Cl	0.08916	±0.00688	± 7.7	228	±21	± 9.2	0.20
1,650 p.p.m. Cl	0.10989	±0.00537	± 4.9	228	±13	± 5.7	0.21
3,650 p.p.m. Cl	0.11547	±0.00560	± 4.8	211	±13	± 6.2	0.30
6,400 p.p.m. Cl	0.12678	±0.00447	± 3.5	206	± 9	± 4.4	0.76
9,100 p.p.m. Cl	0.12247	±0.00400	± 3.3	216	± 7	± 3.2	0.85
13,600 p.p.m. Cl	0.08817	±0.00408	± 4.6	197	±11	± 5.6	0.65
18,150 p.p.m. Cl	0.08667	±0.01036	±11.9	195	±29	±14.9	0.92

C. were made for as long as 76 days. The observations after 34 days only show a gradual increase in the B.O.D. and for the curves having a low concentration of sea water, the onset of the second stage.

At 20° C., the observations to the beginning of the second stage, or the observations for the first 12 days when the second stage was retarded by sea water, were used to compute the constants of the first stage. At 10° C., the observations for about the first 25 days were used to compute the first-stage constants. Several of the curves for the second stage are fitted to the observations by eye rather than by least squares, because there were either too few observations or the second-stage observations were too erratic for mathematical curve fitting.

The unimolecular equation first proposed by Phelps (16), and the inclusion of the lag period, fit the observations better than any of the other formula investigated. Thus,

$$\log \frac{L}{L-X_t} = k(t-t_0)$$

or

$$X_t = L(1-10^{-kt})$$

in which L is the total demand of the stage; X_t is the oxygen used up at any time t; k is the rate constant for a given set of conditions; and t_0 is the value of t at the end of the lag period, that is, $X_t = 0$.

The "slope method" of Thomas (17) (18) was used to compute the rate constant k, the ultimate stage demand L, and the lag period t_0.

The probable errors in k and L are generally small, usually being under 5 per cent, although in a few instances they are over 10 per cent. In most

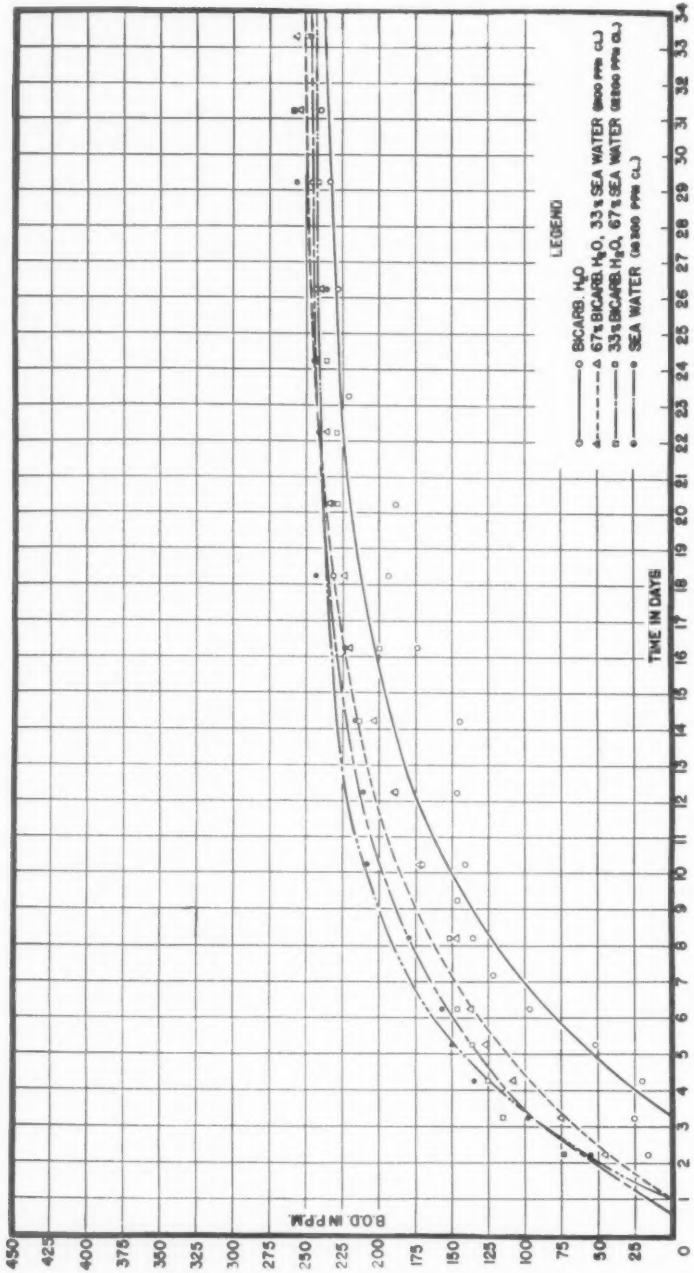

FIGURE 1.—Observed B.O.D., and computed B.O.D. curves of best fit, Series A, 5° C.

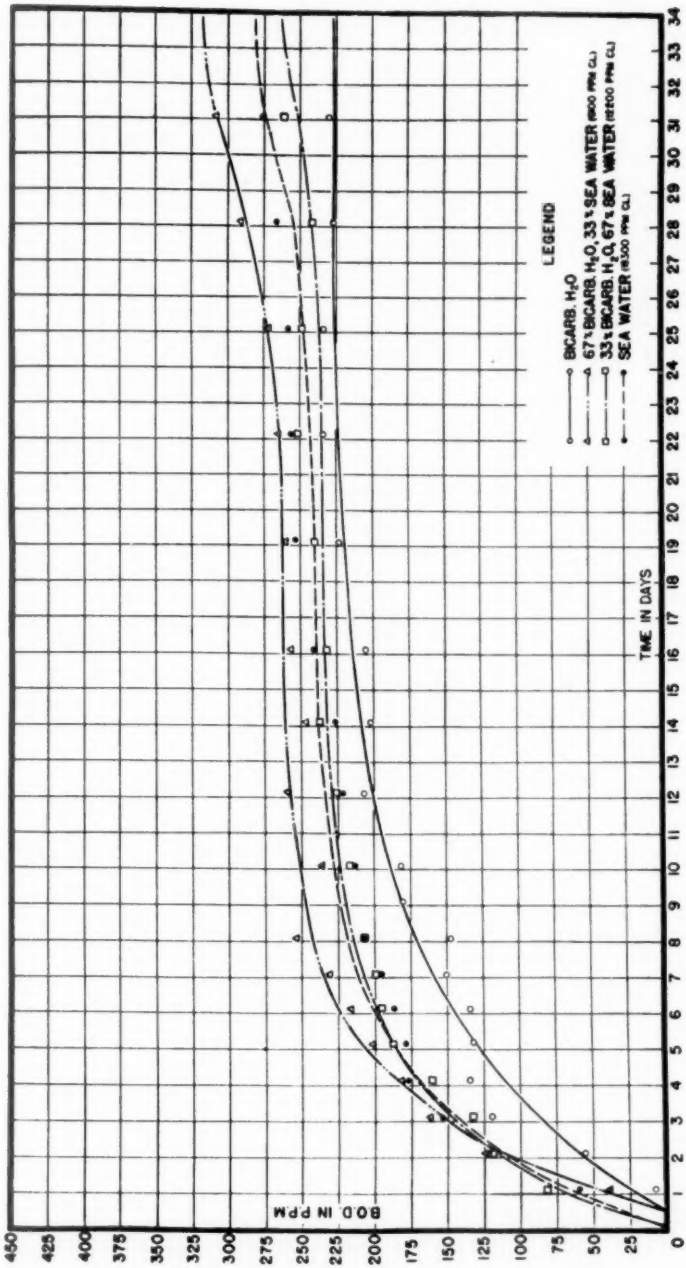
LEGEND
BICARB. H_2O
67% BICARB. H_2O, 33% SEA WATER (6000 PPM CL)
33% BICARB. H_2O, 67% SEA WATER (12600 PPM CL)
SEA WATER (18500 PPM CL)
TIME IN DAYS
BOD IN PPM

FIGURE 2.—Observed B.O.D., and computed B.O.D. curves of best fit, Series A, 10° C.

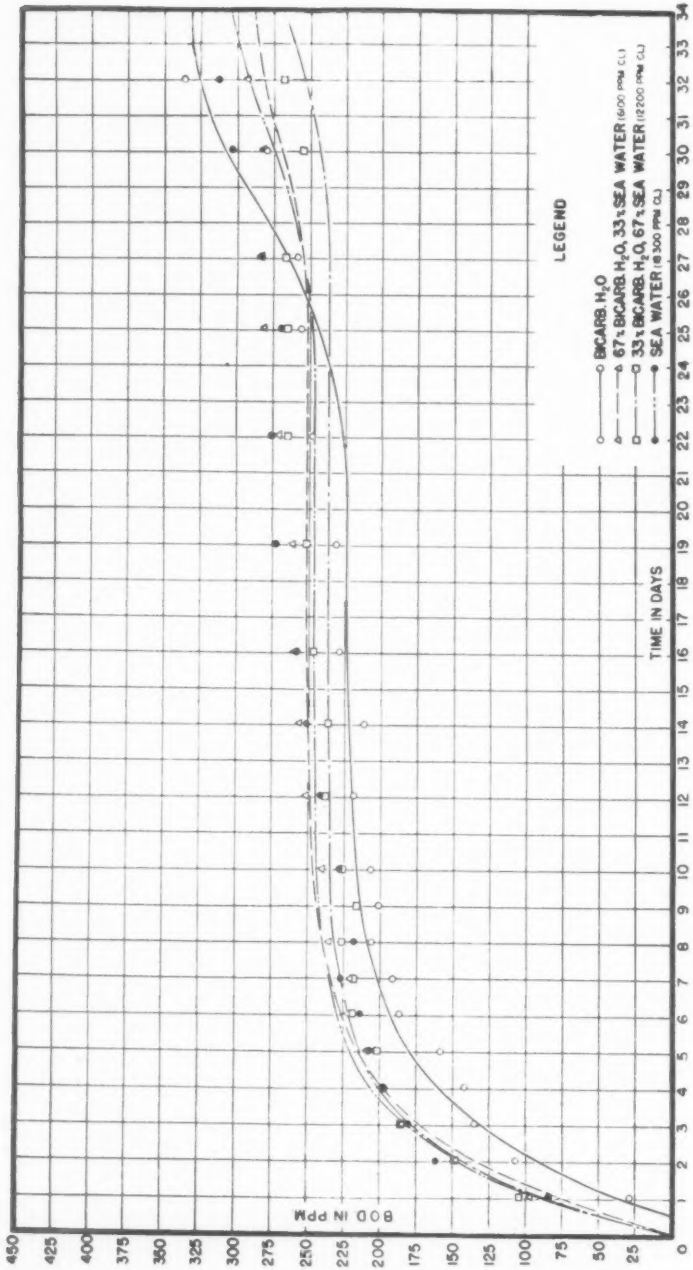

FIGURE 3.—Observed B.O.D., and computed B.O.D. curves of best fit, Series A, 15° C.

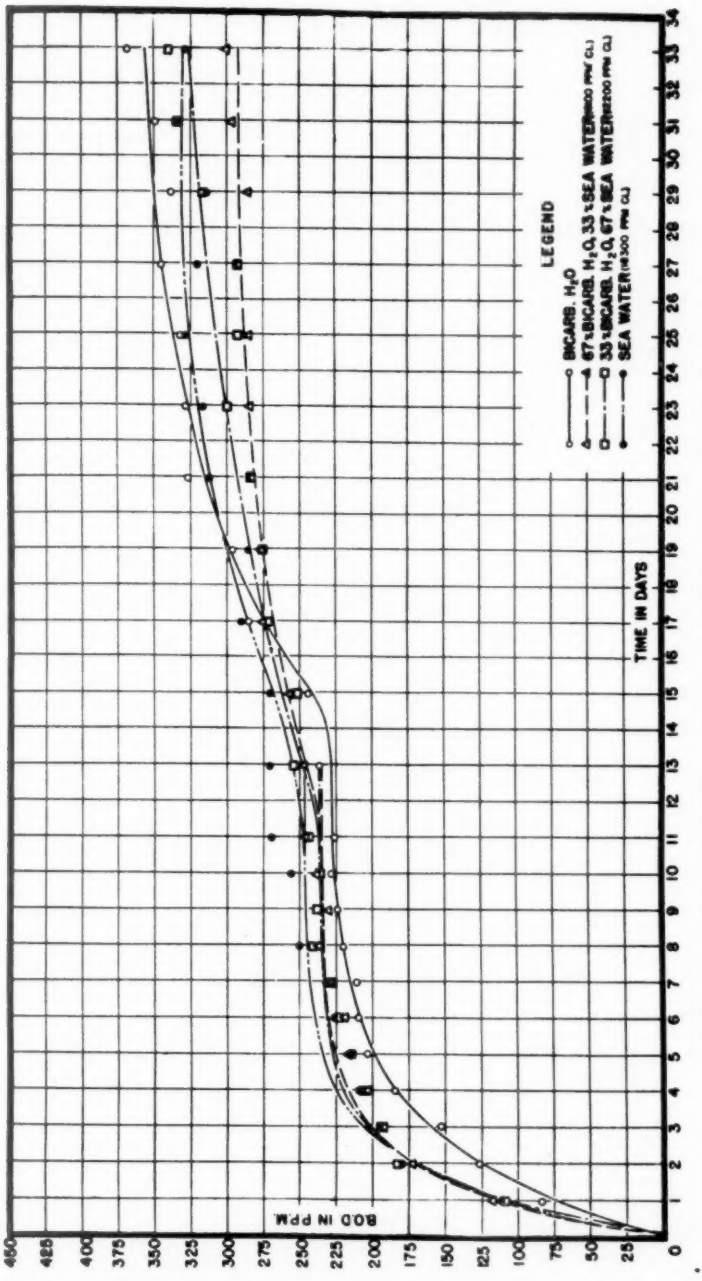
LEGEND
BICARB. H_2O
67 % BICARB. H_2O, 33 % SEA WATER (1000 PPM Cl.)
33 % BICARB. H_2O, 67 % SEA WATER (2200 PPM Cl.)
SEA WATER (5300 PPM Cl.)
TIME IN DAYS
BOD IN PPM

FIGURE 4.—Observed B.O.D., and computed B.O.D. curves of best fit, Series A, 20° C.

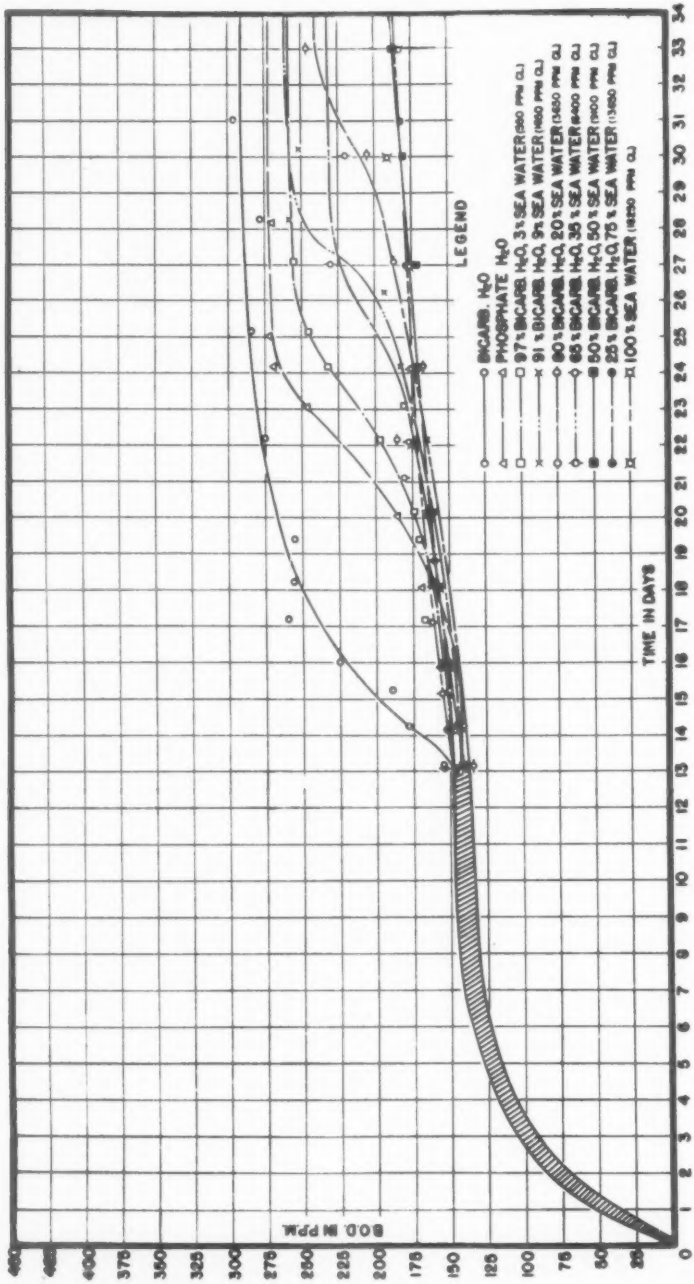
LEGEND
BICARB. H₂O
PHOSPHATE H₂O
97% BICARB. H₂O, 3% SEA WATER (500 PPM Cl.)
91% BICARB. H₂O, 9% SEA WATER (1650 PPM Cl.)
80% BICARB. H₂O, 20% SEA WATER (3450 PPM Cl.)
65% BICARB. H₂O, 35% SEA WATER (6400 PPM Cl.)
50% BICARB. H₂O, 50% SEA WATER (9600 PPM Cl.)
25% BICARB. H₂O, 75% SEA WATER (13250 PPM Cl.)
100% SEA WATER (18250 PPM Cl.)
TIME IN DAYS
BOD IN PPM

FIGURE 5.—Observed B.O.D., and computed B.O.D. curves of best fit, Series B, 20° C.

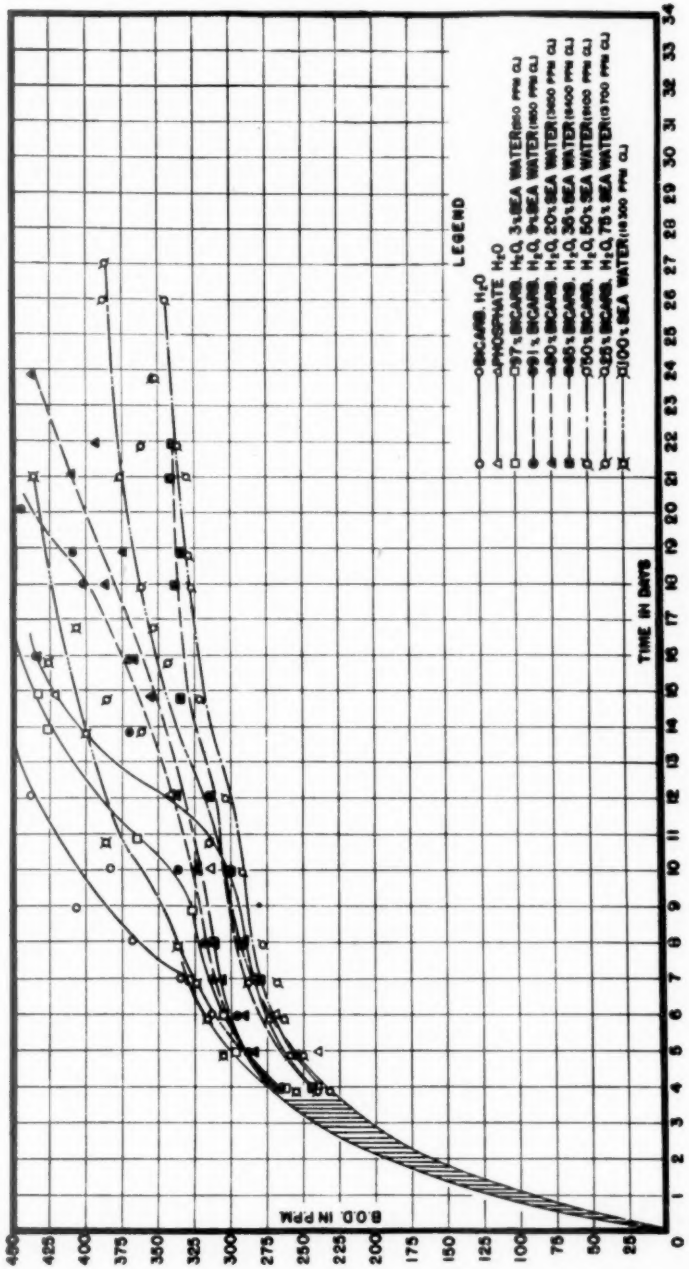

FIGURE 6.—Observed B.O.D., and computed B.O.D. curves of best fit, Series C, 20° C.

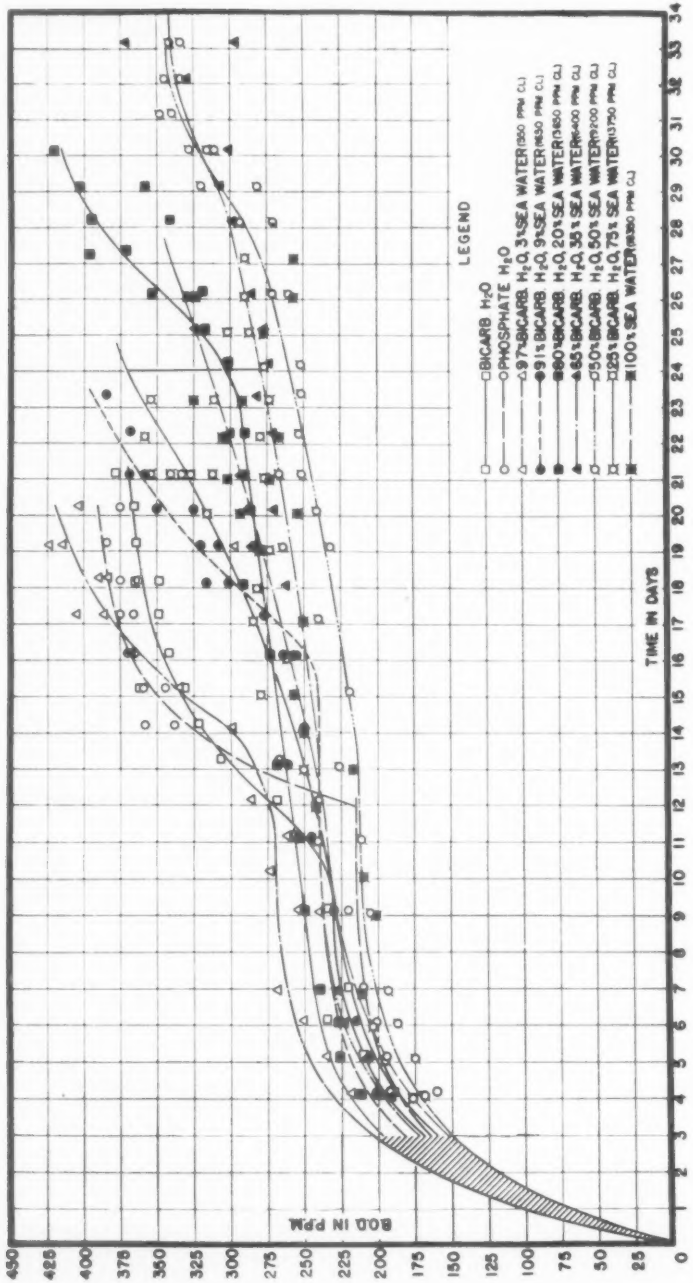
LEGEND
BICARB H_2O
PHOSPHATE H_2O
97% BICARB. H_2O, 3% SEA WATER (350 PPM Cl.)
91% BICARB. H_2O, 9% SEA WATER (1650 PPM Cl.)
80% BICARB. H_2O, 20% SEA WATER (3650 PPM Cl.)
65% BICARB. H_2O, 35% SEA WATER (6400 PPM Cl.)
50% BICARB. H_2O, 50% SEA WATER (9200 PPM Cl.)
25% BICARB. H_2O, 75% SEA WATER (13750 PPM Cl.)
100% SEA WATER (18350 PPM Cl.)
TIME IN DAYS
BOD IN PPM

FIGURE 7.—Observed B.O.D., and computed B.O.D. curves of best fit, Series D, 20° C.

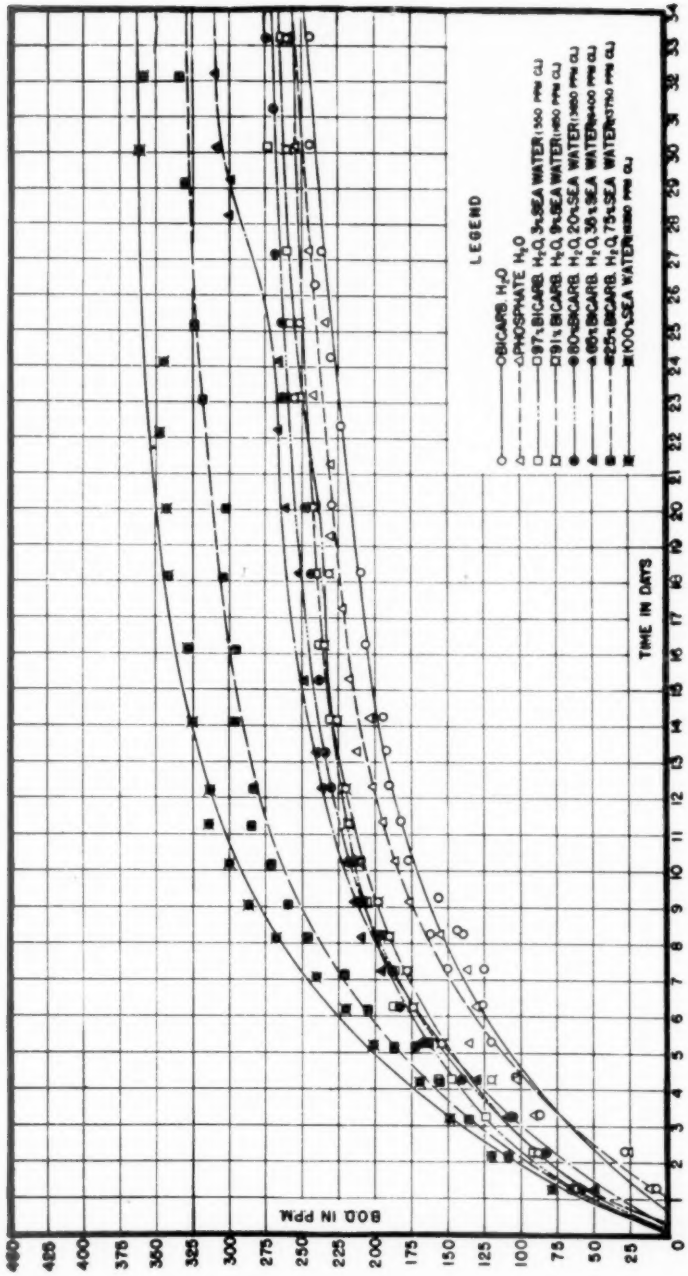

FIGURE 8.—Observed B.O.D., and computed B.O.D. curves of best fit, Series E, 10° C.

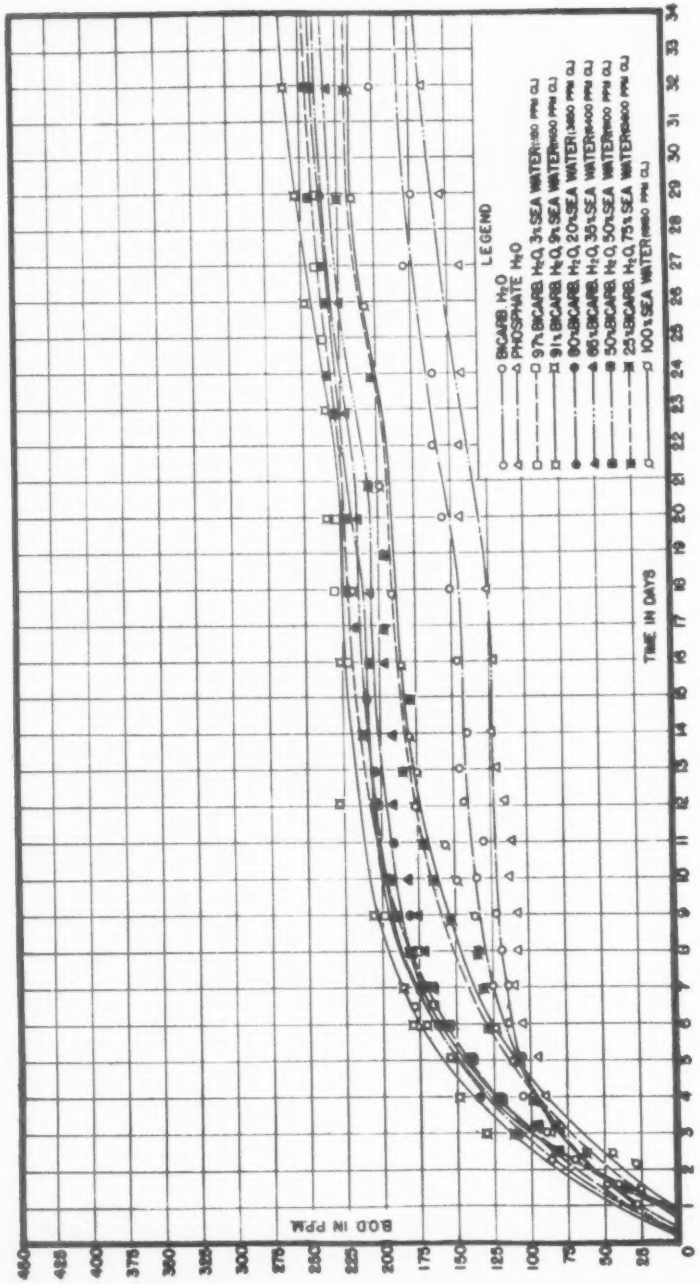
BOD IN PPM
TIME IN DAYS
LEGEND
BICARB. H₂O
PHOSPHATE H₂O
97% BICARB. H₂O, 3% SEA WATER
91% BICARB. H₂O, 9% SEA WATER
80% BICARB. H₂O, 20% SEA WATER
65% BICARB. H₂O, 35% SEA WATER
50% BICARB. H₂O, 50% SEA WATER
25% BICARB. H₂O, 75% SEA WATER
100% SEA WATER

FIGURE 9.—Observed B.O.D., and computed B.O.D. curves of best fit, Series F, 10° C.

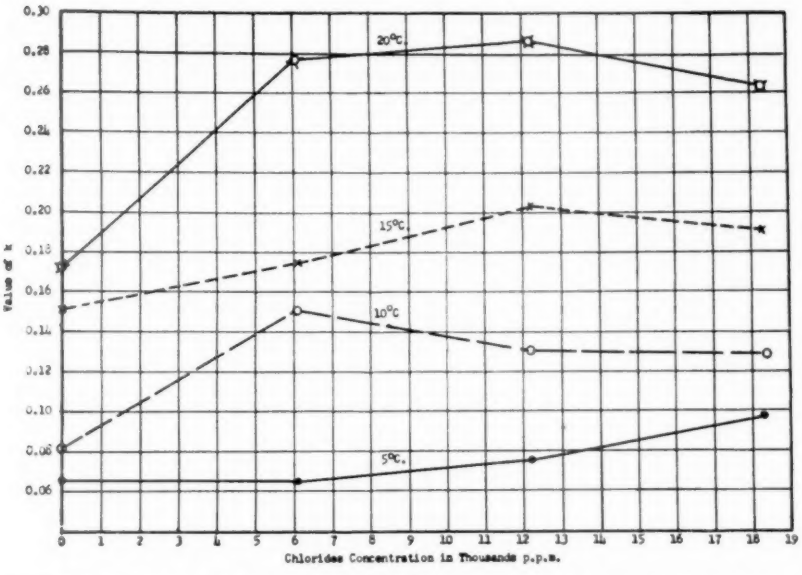

FIGURE 10.—Values of k for different chlorides concentrations in sewage-dilution water mixtures (Series A).

cases the probable errors in k and L of the experiments containing sea water are lower than those for the fresh water experiments.

Effect on Oxidation Rate

Series A.—The relationship of the magnitude of k, the oxidation rate (Table I), to the amount of sea water in the mixtures, expressed as p.p.m. chlorides, of Series A at 5° C., 10° C., 15° C., and 20° C., is shown in Figure 10. It is seen that the values of k are generally somewhat larger in the experiments containing sea water than in the fresh water. The changes in the values for k between the 6,100-p.p.m., 12,200-p.p.m., and 18,300-p.p.m. chlorides concentration experiments at the different temperatures is not significant. The probable errors in the magnitude of k in the 5° C. and 10° C. bicarbonate water experiment and the 20° C. sea water experiment are high. Inasmuch as the computed curves do not fit the observations well this may partially account for the larger values of k in sea water than in fresh water.

Series B, C, and D.—The relationship between the magnitude of the rate of oxidation k and the concentration of sea water for Series B, C, and D, at 20° C. (Tables IIa, IIb, and IIc), is shown graphically in Figure 11. The value of k for fresh water in each of the respective series is the average of the k for the bicarbonate water and the phosphate water curves. In Series B, the value of k is largest for 550 p.p.m. chlorides, and decreases rapidly until it is about the same magnitude as for fresh water at between 3,650 and 6,400 p.p.m. chlorides. The magnitudes of k continues to decrease as the chlorides increase, until with straight sea water the value of k is about 81 per cent of that for fresh water. In Series C, k is a little smaller for 550 p.p.m. chlorides than the mean k for the fresh water experiments, but increases to 16

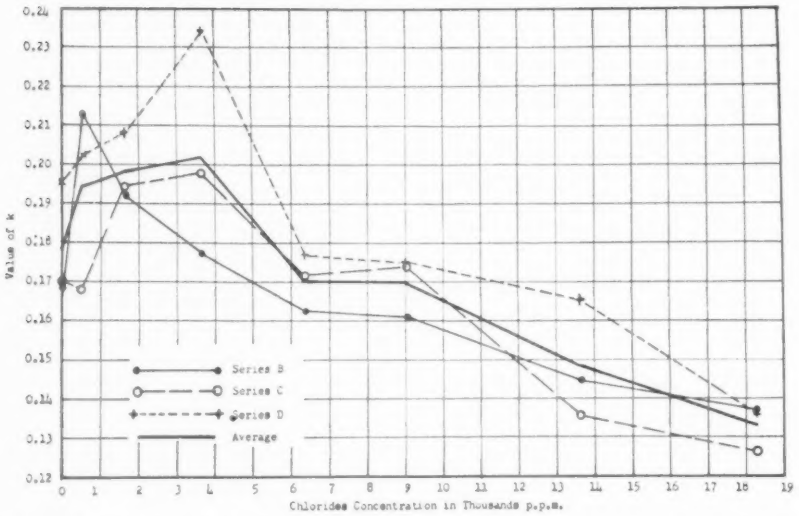

FIGURE 11.—Values of k for different chlorides concentrations in sewage-dilution water mixtures (Series B, C, and D).

per cent larger than that of fresh water at 1,650 and 3,650 p.p.m. chlorides. At 6,400 and 9,100 p.p.m. chlorides the values of k are about the same as fresh water, but k decreases as the concentration of sea water increases, until in straight sea water the value of k is about 75 per cent of that for fresh water. The magnitude of k in Series D is greatest at 3,650 p.p.m. chlorides, where it is about 17 per cent larger than for fresh water; the magnitude of k then decreases sharply to 90 per cent of the fresh water value at 6,400 p.p.m. chlorides and continues to decrease steadily until, for straight sea

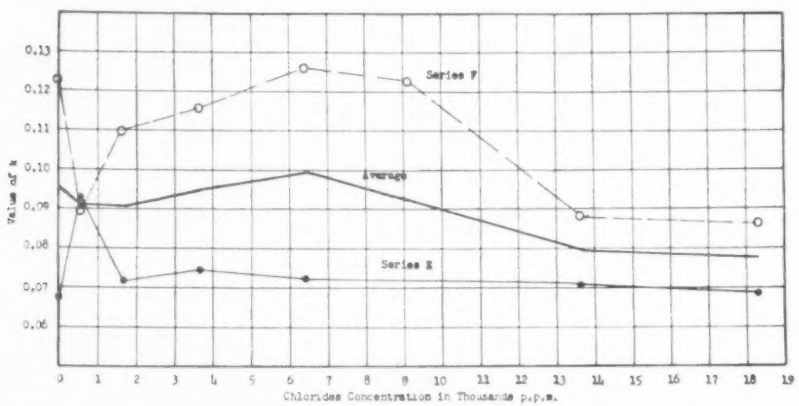

FIGURE 12.—Values of k for different chlorides concentrations in sewage-dilution water mixtures (Series E and F).

water, it is about 70 per cent of the value in fresh water.

Series E and F.—Figure 12 shows graphically the relationship of the magnitude of k for Series E and F, at 10° C. (Tables IId and IIe), to the concentration of sea water. The relationship is not as consistent as for Series B, C, and D, at 20° C. Series E shows a higher value for k with 550 p.p.m. chlorides than with fresh water, but little variation for the other sea water mixtures. In Series F, the magnitudes of k in the fresh waters are very high and for 550 p.p.m. chlorides very low. The magnitude of k decreases with an increase in sea water concentrations above 9,100 p.p.m. chlorides. When Series E and F are averaged, a downward trend in the value of k for sea water concentrations above 6,100 p.p.m. chlorides is indicated.

Ruchhoft, Placak, Kachmar, and Calbert (19), the author (15), and many others have found that k may vary considerably for the same sewage. However, k is the most satisfactory method at present available for describing the rate of biological oxidation of sewage. Although the relationship of k to the concentration of sea water is not entirely consistent in all the experiments, in general the results indicate that in mixtures having a low concentration of sea water the value of k is slightly higher than the value of k in fresh water, but that when the sea water concentration is greater than 50 per cent k decreases to a value slightly lower than that for fresh water.

There is little quantitative information available on the magnitude of k for the biochemical oxidation of sewage in different concentrations of sea water. Adeney's (2) early investigations of long-time biochemical oxidation of sewage in fresh and sea water were probably the first experiments which permit the computation of k. In the two different series of experiments by Adeney in which 20 per cent sewage was incubated at 15° C. to 18° C. after dilution with fresh water and with sea water, computation by the "slope method" for the first stage of oxidation show values of k of 0.2564 for the fresh water experiment and 0.2087 for the sea water experiment. The other series of Adeney shows k to be 0.1716 for fresh water and 0.2039 for sea water.

Baity (11) observed the biochemical oxidation of sewage in fresh water and sea water at 20° C. and 25° C., and at 20° C. in a synthetic sea water having 10,000 p.p.m. salinity. The values of k computed by the "slope method" for the first stage of oxidation are as follows:

Sewage Dilution	Values of k At 20° C.	Values of k At 25° C.
2% in fresh water	0.1326	0.2308
2% in 10,000-p.p.m. salinity	0.1086	———
2% in sea water	0.1413	0.1698

The results of both Adeney (2) and Baity (11) show only small variations as to the effect of sea water on the rate of biochemical oxidation. It is probable that the variation in k due to factors other than sea water may be as large as that caused by the sea water.

Clark (9) (10), from research on the oxidation of sewage in fresh and sea water in connection with the Charles River Basin, reported that "In every case and with all the various percentages of mixture it was found that the oxygen disappeared very much more rapidly in salt water than in fresh water." His conclusions were based on short tests and he did not determine the curve of biochemical oxidation and the rate constant, k.

Effect on Ultimate First-Stage B.O.D.

Series A.—It is seen in Table I and in Figures 1, 2, 3, and 4 that the differences in the magnitudes of the first-stage B.O.D., L, for the different concentrations of sea water at the respective temperatures are small. In Figure 13, the first-stage B.O.D.'s are plotted, in terms of the average first-

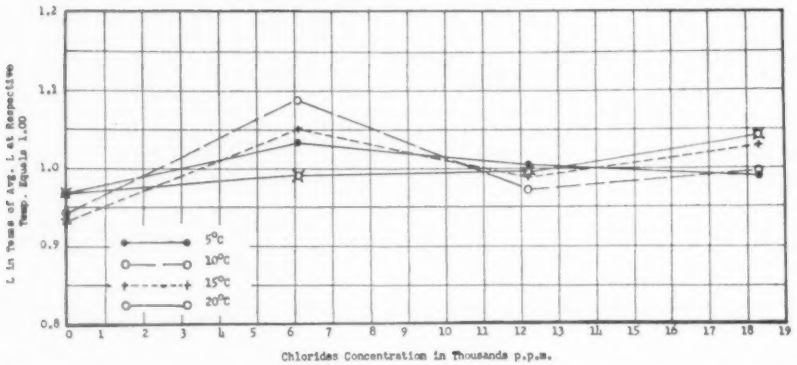

FIGURE 13.—Ultimate first-stage B.O.D., L, for different chlorides concentrations in sewage-dilution water mixtures (Series A).

stage B.O.D. for the different dilution waters at the respective temperature equals 1.0, against the sea water concentration as p.p.m. chlorides. Except at 20° C., the B.O.D.'s of the sewage in bicarbonate water are lowest, and the B.O.D.'s in the sea water mixture having a chlorides concentration of 6,100 p.p.m. are the highest. However, the differences are too small to be significant.

Series B, C, and D.—Figure 14 shows the first-stage B.O.D.'s for Series B, C, and D (from Tables IIa, IIb, and IIc and Figures 5, 6, and 7) plotted, in terms of the average B.O.D. for the different dilution waters of the respective series equals 1.0, against the sea water concentration as p.p.m. chlorides.

There is very little variation in the first-stage L values for the different sea water concentrations in Series B. In fact, the differences are only slightly greater than the probable error in computing L from the observations. In Series C, the variations in the first-stage L values are a little larger. However, the smallest and largest sea water concentrations yield the largest first-stage B.O.D.'s, which would indi-

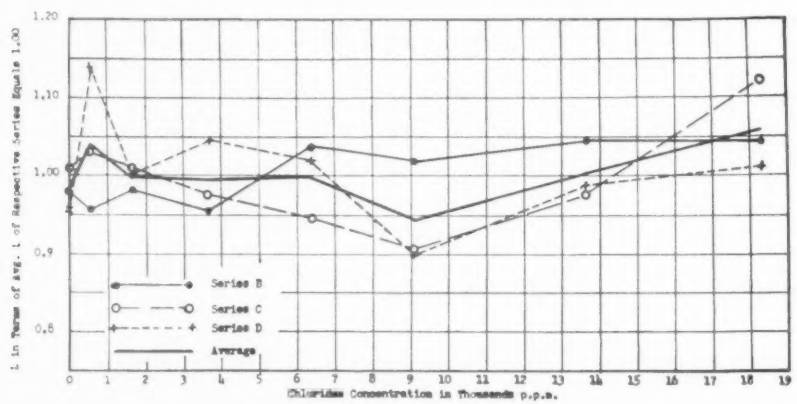

FIGURE 14.—Ultimate first-stage B.O.D., L, for different chlorides concentrations in sewage-dilution water mixtures (Series B, C, and D).

cate that the differences are not due to the sea water. In Series D, the B.O.D. for the lowest sea water concentration (550 p.p.m. chlorides) is the largest, and the other values are nearly the same. The smallest first-stage B.O.D.'s were found in the phosphate dilution water and the 50 per cent sea water mixture. The curve in Figure 14 which is the average of the three series indicates that the sea water had no significant effect on the first-stage L value.

Series E and F.—The results of Series E (Table IId and Figure 8) show that the first-stage B.O.D. increased as the sea water concentration increased, particularly at the higher sea water concentrations. This is inconsistent with the other series. The sea water used in this experiment was allowed to become stabilized before using it in the dilutions, and tests showed the sea water to be free of a significant B.O.D. However, comparison of the results with those of the other series indicates that possibly the sea water had a B.O.D., or that a mistake was made in the quantities of sewage added to the dilution water in setting up the experiments of this series.

It is seen (Table IIe and Figure 9) that the magnitudes of the first-stage B.O.D.'s of Series F are slightly smaller in the experiments containing the larger amounts of sea water than those of the experiments containing the smaller amounts of sea water. However, the differences are so small that they probably are not significant. The B.O.D.'s of the experiments in which bicarbonate and phosphate water was used for dilution were much smaller than those of the experiments which contained sea water.

The two experiments of Adeney (2) in which long-time oxygen demand studies were made in mixtures of 20 per cent sewage in fresh water and sea water at 15° C. to 18° C. show about the same oxygen demand for fresh water and sea water in one experiment; in the other, the oxygen demand of sewage in sea water was considerably higher than in fresh water. Using the observations for the first 13 days, the writer computed the first-stage oxygen depletion for Adeney's first experiment to be 28.79 ml. of oxygen for fresh water, and 29.34 ml. of oxygen for sea water; for the second experiment, 19.62 ml. of oxygen for fresh water, and 24.02 ml. of oxygen for sea water.

Adeney concluded that sea water had little or no effect on the magnitude of the first-stage B.O.D. He attributed the lower B.O.D. in fresh water of his second experiment to the softness of the fresh water used for dilution and, possibly, the CO_2 produced which was not buffered by alkalinity, inhibited the normal oxidation by bacteria.

Baity's results (11) on long-time biochemical oxidation of sewage in fresh water and sea water are as follows:

Sewage Dilution	Values of L (as p.p.m. O_2 depletion) At 20° C.	At 25° C.
2% in fresh water	4.34	4.43
2% in 10,000-p.p.m. salinity	5.38	———
2% in sea water	3.19	2.99

Except for the 10,000-p.p.m. salinity experiment at 20° C., these results indicate that sea water depressed the magnitude of the first-stage B.O.D. of sewage. Baity's experiments were not seeded with organisms other than those present in the sewage. It is possible that the lowering of the first-stage B.O.D. by sea water may have been brought about by the bacteria not being acclimatized to the sea water medium.

Clark (9) (10) concluded that the B.O.D. of sewage was greater in sea water than in fresh water. His conclusions were drawn from studies involving determination of the time necessary for the depletion of the dissolved oxygen, which was the determination

of the amount of oxygen consumed in relatively short periods of time. As the magnitude of k could not be determined and has an important bearing on the first-stage B.O.D. determined from short time observations, it should not be concluded from his results that the actual ultimate first-stage B.O.D. is larger in sea water than in fresh water. His results do indicate that the sea water affected either k, or L, or both, so that the B.O.D. exerted by sewage during the period of incubation was larger in sea water than in fresh water.

There have been several reports on the effect of various inorganic salts in the dilution water on B.O.D. Although the results vary somewhat, in general it has been found that there are pronounced differences in B.O.D.'s of some sewages in different dilution waters, and those waters having low salt concentrations gave low B.O.D.'s. It appears that when there is no deficiency in the mineral salts needed for biochemical oxidation, the reaction is maintained in the desirable range, and there are not toxic chemicals, the effect of small differences in the salt content on the first-stage B.O.D. is not significant.

Effect on Lag Period

The magnitudes of the lag period for the different series of experiments are shown in Tables I and II. It is seen that, except for Series F, the lag period is less in the sea water mixtures at 5° C., 10° C., and 15° C. than in the fresh water. Greenfield and Elder (20) and Greenfield, Elder, and McMurray (21) in studying the lag period at 2° C. found that its duration was affected by seeding with low temperature organisms and that the increase in numbers of bacteria is very slow during the first few days at low temperatures. Butterfield and Wattie (22) showed the lag period to be dependent on the number of bacteria present in the initial mixture, which is in turn dependent on the amount of seeding.

The experiments shown here were all seeded with the same volume of acclimatized seed, which had been developed for the same period of time. It would seem that the number of bacteria in the seed material should hardly be responsible for the shorter lag period in the experiments containing sea water. Exactly what in the sea water reduces the lag period at the lower temperatures of incubation is difficult to say. Bacterial examination of the stabilized sea water used for dilution showed low counts. The minerals in the sea water may possibly accelerate the metabolism and reproduction of the bacteria. There seems to be no such relationship, however, between the magnitude of k due to increased metabolism and reproduction and the lag period.

Effect on Second-Stage Biochemical Oxidation

This investigation was primarily concerned with the first stage of biochemical oxidation. However, the observations made for the biochemical oxidation curves show some interesting effects of sea water on the second, or nitrification, stage. It was not feasible to make determinations for the changes in the different forms of nitrogen parallel with the oxygen determinations, so it is necessary to assume that when the trend of oxygen depletion indicates a second stage, nitrification has started. This does not mean that no nitrification has taken place before a well pronounced second stage appears. It can be seen from the B.O.D. observations that in some cases the second stage apparently developed gradually and showed no very pronounced curve.

The B.O.D. curves for Series B, C, and D, at 20° C. (Figures 5, 6, and 7) indicate the effect of sea water on the second stage. In Series B (Figure 5), the bicarbonate dilution water experi-

ment started the second stage first, followed by the phosphate water, the 3 per cent sea water, the 9 per cent sea water, the 20 per cent sea water, and the 35 per cent sea water. The curves for the experiments with 50, 75, and 100 per cent sea water did not show a definite second stage during 37-day incubation, but the oxygen depletion increased gradually during that time.

The curves of Series C (Figure 6) indicate a somewhat similar condition, except that the 100 per cent sea water curve showed a typical second stage before some of the experiments having smaller concentrations of sea water.

The experiments of Series D (Figure 7) also show the effect of sea water in delaying or suppressing the second stage. In this series the second stage occurs first in the bicarbonate and phosphate dilution waters, and later in the experiments containing sea water. Except for the experiment containing 75 per cent sea water, the larger the concentration of sea water the more the second stage was delayed.

The Series A experiments at 15° and 20° C. indicate that sea water depressed the second stage, but not to as great a degree as in Series B, C, and D.

The second-stage observations for Series E and F at 10° C. are not shown (Figures 8 and 9) because a second stage was not reached at the low temperature until after 50 or more days. Some of the curves of these series were observed for as long as 76 days and indicated the delaying and suppressing effect of sea water on the second stage.

The oxygen depletion observations during the period of the second stage in the experiments containing larger concentrations of sea water vary considerably. Rarely do the observed points fit a second-stage curve for experiments containing sea water as well as they do for fresh water.

Mohlman, Edwards, and Swope (23) observed the changes in nitrogenous material parallel with observations on oxygen depletion and found that the oxidation of nitrogenous material paralleled very closely the second stage of biochemical oxygen demand. Assuming that the second-stage curves in the sea water experiments represent nitrification, it appears that nitrogenous material undergoes nitrification in sea water.

Purvis and associates concluded from their studies on nitrification in sea water (5) (6) (7) that nitrification due to nitrifying bacteria did not take place in sea water. Several early studies indicated that nitrification did not take place in sea water. Nevertheless, Von Brand, Rakestraw, and Renn (24) (25) have reproduced the nitrogen cycle in sea water. Different investigators have shown that different salts such as calcium chloride and magnesium hydroxide had a pronounced effect on the second stage of oxidation.

It appears that sea water does retard the second stage, but that in time oxidation equivalent to the second stage in fresh water will take place in sea water.

Conclusions

1. The results show that the rate of biological oxidation, k, varies considerably under similar conditions. In general, the data indicate that in low concentrations of sea water (up to about 25 per cent) k is larger than in fresh water. As the concentration of sea water is further increased the magnitude of k decreases until in straight sea water it is less than in fresh water.

2. Sea water does not significantly affect the magnitude of the first stage of biochemical oxidation of sewage.

3. The lag period of the first stage of oxidation at low temperatures is usually shorter in waters containing some sea water than in fresh waters.

4. The second stage of biochemical oxidation takes place in sea water, but is retarded.

Acknowledgment

The research work reported in this paper was done during graduate study

in the Harvard University School of Engineering. The author wishes to express credit, appreciation, and thanks to Dean G. M. Fair, under whose direction the research was done. Appreciation is also expressed to Professors H. G. Baity, Edward W. Moore, Harold A. Thomas, and M. C. Whipple for their cooperation and helpful advice on several aspects of the work.

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MICHIGAN REVAMPS POLLUTION CONTROL AGENCY

As a result of recent legislation, Michigan has broadened the scope of its water pollution control agency and reconstituted it on a more logical working basis. Principal changes resulting from the far-reaching action are:

1. The 5-man inter-departmental Stream Control Commission has been converted into the 7-man Water Resources Commission, composed of four of the original members plus three new appointees by the Governor.

2. The scope of water control in Michigan has been broadened from pollution abatement alone to include agency responsibility, at least, for such other problems as groundwater, flood control, and beach erosion.

3. The old definition of unlawful pollution has been broadened in such a way as to protect industries or "other lawful occupations," wildlife, fish, and wildlife values.

4. Provision has been made for liquidating new sources of pollution before they become established.

5. The penalty for "willful" violation has been increased from $100 to $500 per day, and the old unused jail sentence has been eliminated.

NOTES ON THE PREPARATION OF A NITRITE CONCENTRATION CURVE

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The use of instrumental standards for colorimetric work has increased greatly during recent years. It is sometimes forgotten that instruments provide results that must be classified as secondary standards, and that the accuracy of the results obtained is only as good as the reproducibility of the method used for constructing the concentration curve and determining the substance sought. Fortunately, most of the determinations made on water and sewage do not demand an extreme degree of precision, but as high a degree of accuracy as possible is desired.

This paper is a report on the construction and reproducibility of the concentration curve used with the spectrophotometer for the determination of nitrites.

It had previously been noted that the alpha-naphthylamine base used as a coupling reagent in the standard method (1) deteriorated rather rapidly. Also, as the solution became older the oxidized portion deposited on the sides of the bottle. Rider and Mellon (2) suggest the use of alpha-naphthylamine hydrochloride in hydrochloric acid solution because of the better keeping qualities of the base, and of the reagent, as they prepare it. Tests made on the keeping qualities of the alpha-naphthylamine hydrochloride crystals showed them to be much superior to that of the base. In addition, the alpha-naphthylamine hydrochloride dissolved rapidly and completely. A solution of 6 gm. of purified alpha-naphthylamine hydrochloride in 1 liter of 5N acetic acid was compared with a solution of 5 gm. of alpha-naphthylamine in 1 liter of 5N acetic acid as a coupling reagent for identical standard solutions. These solutions were equivalent in alpha-naphthylamine content. There was no detectable difference between the results secured with each reagent, and because of its stability and ease of preparation it was decided to use the alpha-naphthylamine hydrochloride acetic acid solution in the present investigations.

The standards used in the determination of nitrite were prepared according to Standard Methods for the Examination of Water and Sewage (1), with the exception noted. All determinations were made with a Coleman model 11 spectrophotometer using the 525 mm. transmission band with a reagent reference and a 19-mm. round cell. A series of standards (0.02 to 0.48 p.p.m.) was made up in 50-ml. tubes, using from 2 ml. to 48 ml. of standard solution (0.001 mgm. to 0.024 mgm.) of NO_2 as nitrogen. The percentage transmissions were recorded as shown in Table I. Despite similar technique except as noted, satisfactory duplicate readings could not be obtained. This table, however, does show the necessity of mixing thoroughly.

TABLE I.—Percentage of Transmission for Various Standard Dilutions

Volume of Standard (ml.)	Mixed After 2nd Reagent Only	Mixed After Each Reagent	
2	86.8	82.1	82.3
6	65.6	57.8	58.8
12	38.3	36.2	36.1
18	23.3	23.5	23.0
24	15.9	16.7	15.9
30	12.9	11.4	15.1
36	18.0	10.2	17.0
42	11.8	8.9	15.9
48	8.3	—	9.9

Obviously, the results were hopelessly inconsistent from about 24 ml. on up. It seemed not unlikely that the time of standing in contact with the reagents and the time of standing before reading might be an important factor. It was noted that a precipitate formed in the tubes containing larger amounts of nitrite, that this precipitate could be dissolved in alkali, and that a considerable portion of the original color could be recovered by acidification with hydrochloric acid. A trial was made to ascertain if raising of the pH might prevent precipitation. If the pH were raised only slightly (not above 4.0) precipitation was not affected. Higher pH (4.8 and higher) changed the red color to brown. Sodium acetate or alkali had similar effects within the range pH 3.0 to 4.8. The initial pH, as made up with distilled water, was 2.75 minimum.

TABLE II.—Effect of Addition of Concentrated HCl on Percentage Transmission

HCl (ml.)	Time of Reading					
	1 min.	5 min.	10 min.	20 min.	60 min.	120 min.
0.05	10.9	10.9	10.9	10.9	11.1	21.1
0.10	10.9	10.8	10.9	10.9	11.1	16.2
0.2	11.0	10.9	11.0	10.9	11.1	13.1
0.4	11.1	11.0	11.0	11.0	11.1	12.1

A trial was then made using varying amounts of concentrated hydrochloric acid. One ml. of sulfanilic acid was added to each tube, mixed, and allowed to stand for 7 min. One ml. of alpha-naphthylamine hydrochloride was then added and, after 10 min. more, the remainder of the hydrochloric acid. Transmission readings were made at various times to determine the deterioration. In all cases, 30 ml. of standard solution (0.015 mgm. NO_2 nitrogen per 50 ml.) was used (see Table II).

This was more encouraging, and a check was made on a complete set of

TABLE III.—Percentage of Transmission for Various Standard Dilutions with 0.5 Ml. HCl Added

Volume of Standard (ml.)	Time of Reading	
	10 min.	30 min.
2	83.8	82.1
6	60.0	57.9
12	37.0	35.1
18	24.9	23.4
24	15.9	15.0
30	11.8	12.0
36	9.0	9.1
42	6.9	6.9
47	7.0	6.1

standards using 0.5 ml. of hydrochloric acid before coupling (see Table III).

The results indicate that the addition of hydrochloric acid before coupling retards the development of the color. The following method was then adopted. To the 50-ml. tubes containing the standards, 1 ml. of sulfanilic acid was added. The solutions were mixed thoroughly by inverting the tube and permitting it to stand for 7 min. to ensure complete diazotization. One ml. of alpha-naphthylamine hydrochloride solution was added and the solutions were mixed again. After 5 min., ½ ml. of concentrated hydrochloric acid was added, the solution was made up to volume, and the percentage transmission was read immediately. Two separate sets of standards were made up and the transmissions recorded (Table IV).

The last four solutions of the second series were made up with a fresh solution of sulfanilic acid, which was not completely dissolved. This might account for the difference in this group.

TABLE IV.—Transmission Percentages for Two Sets of Standards Made by Proposed Method

Volume of Standard (ml.)	Set Number	
	1	2
2	82.9	82.9
6	58.2	59.0
12	36.1	36.3
18	23.3	23.7
24	16.1	16.1
30	11.8	12.3
36	9.1	10.0
42	7.4	7.9
47	6.3	7.0

However, these results in themselves did not agree too well with some previously obtained, and it was thought that the trouble might be caused by deterioration of the intermediate standard solution. With this in mind, a new set of standard solutions was prepared. A set of nitrite standards was made up as previously described, and transmission readings were made. Two days later this process was repeated, and the results tabulated (Table V).

A recheck of the 2-ml. standard gave a value of 82.0. The averages of the values given in Table V were plotted on semi-logarithm paper against the concentration of nitrite nitrogen in the standards. It was found that a smooth curve could be drawn through all points (Figure 1). In using the curve, the parts per million of nitrite in the sample are found by dividing the volume to which the sample is diluted by the volume of the sample, and multiplying the result by the reading in parts per million.

TABLE V.—Transmission Percentages of Check Standards

Volume of Standard (ml.)	Set Number 1	2
2	81.9	82.7
6	56.7	57.1
12	34.3	34.5
18	21.9	22.0
24	15.0	14.8
30	10.7	10.3
36	8.1	7.9
42	6.4	6.4
47	5.9	5.9

With the thought that a protective colloid in the solution might prevent the precipitation of the nitrite color-producing compound, trials were made with gelatinized starch and with gum

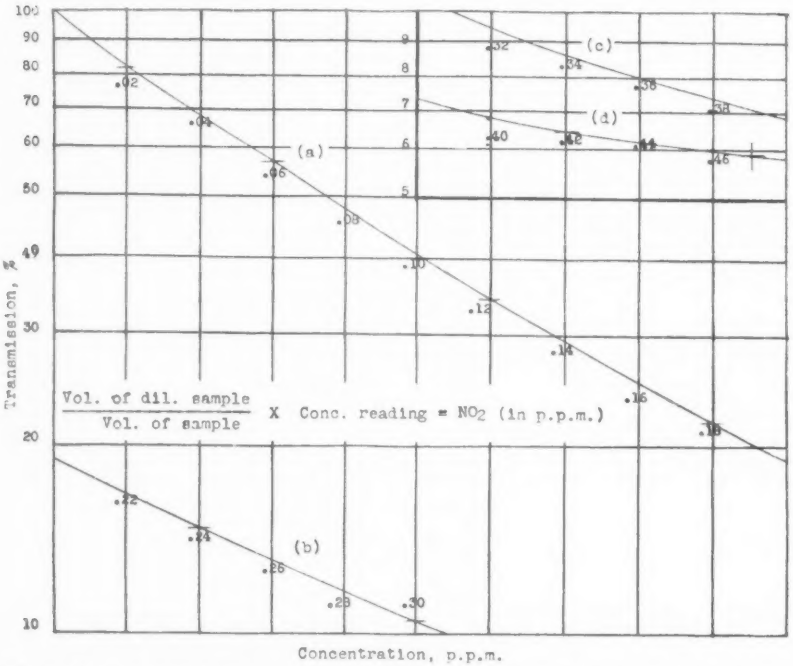

FIGURE 1.—Standard solution concentration curve for spectrophotometric determination of nitrite as nitrogen. (Wave length, 525 millimicrons; cell, 19 mm. round.)

arabic. These were compared to hydrochloric acid, but neither seemed to work well except in very heavy concentrations, which interfered by absorbing light. Neither was as good as the acid under the conditions used.

Recovery of the precipitated color was also tried. A standard was made up with 25 ml. of standard solution, but without acid. The initial transmission of this standard was 16.2 per cent. After 24 hr., the transmission was 71.6 per cent. Addition of ½ ml. of 50 per cent NaOH dissolved the precipitate completely, and turned the tube brown. With further addition of 1.8 ml. of concentrated hydrochloric acid the original color returned. The transmission was 15.9 per cent, which, when calculated back to the original volume, corresponded to a transmission of 15.1 per cent. This seems to indicate that the recovery is nearly quantitative.

Summary

It is recommended that alpha-naphthylamine hydrochloride be used in place of the free base. The superior keeping qualities of the hydrochloride and its ease of solution recommend it for regular use.

A nitrite nitrogen concentration curve for the spectrophotometer and permitting good reproducibility is presented. This curve appears to follow the Beer law to about 0.06 p.p.m. of nitrite nitrogen. Beyond this concentration, there is considerable deviation.

A method of preventing the precipitation of the dye complex is shown to extend the usable range of the curve. The acid used seemed to have no effect on the intensity or quality of the color in the lower concentrations of 0.12 p.p.m. or less.

Conclusions

In the colorimetric determination of nitrites, a spectrophotometer may be used to attain an accuracy on the order of that of a gravimetric or volumetric analysis (1 per cent or less).

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A PROCEDURE FOR DETERMINING SETTLEABLE SOLIDS IN SEWAGE

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This discussion refers to data developed by the investigations of the East Bay Cities Sewage Disposal Survey (1), a study conducted in 1940–41 by a board of consulting engineers to determine a plan of regional sewerage for the various cities located on the east shore of San Francisco Bay. During the course of these investigations, a comprehensive laboratory study was made of the flocculating and settling characteristics of composite sewage samples taken from 10 main outfalls in the area.

The laboratory flocculation studies (2) were conducted with the usual laboratory stirring battery, with which 200-ml. portions of the samples were stirred for periods of 15 min. at a paddle speed of 72 r.p.m. Following a subsequent 20-min. period of quiescence, the top 100 ml. of the test portions were poured off and reserved for measurement of turbidity, suspended solids, and B.O.D. Various coagulant chemicals were employed as flocculating agents, but in the test series for each sample one portion was stirred and settled as a blank, without any chemicals being added. At the same time observations were also made of the rates of removal of settleable particles from the same samples of sewages under conditions of plain sedimentation, again in 200-ml. jars. For each sample a series of jars was employed, so that the reduction in settleable matter could be determined for varying intervals of time; thus, for each sample a settling or sedimentation curve was prepared.

In tabulating and analyzing the data it was noted that the settling curves appeared to be hyperbolic in shape. In fact, it was deduced that the shape of the settling curve should be closely approximated by a hyperbola of the type:

$$R = \frac{t}{b + kt}$$

wherein R is the percentage of removal of suspended matter, t is the time elapsed since beginning of quiescence, and b and k are constants. Figure 1 shows two curves of this type—one for suspended solids removal and one for B.O.D. removal—which represent the average results for the 10 composite samples tested. The value of R, although increasing at a decreasing rate, gradually approaches the asymptote to the curve, which is mathematically expressed by $1/k$. In other words, if the settling were to continue for an indefinite period of time, without change in the composition of the sewage, R would eventually approach $1/k$ as a limit. The value of $1/k$, therefore, represents 100 per cent settling removal, or the maximum that can be removed by plain settling extending over an indefinite period of time.

For each of the 10 samples the asymptote values of $1/k$ were determined by the method of replotting the data so as to form the straight-line equivalent of the hyperbolic curve; that is, $t/R = b + kt$. Thus, values of t/R were plotted against t, and the value of k was scaled off as the slope of the straight-line curve. Figure 1 illustrates the straight-line counterparts to the two hyperbolas previously mentioned.

It was then noted that these $1/k$-values were, for each of the 10 samples, practically identical with the values

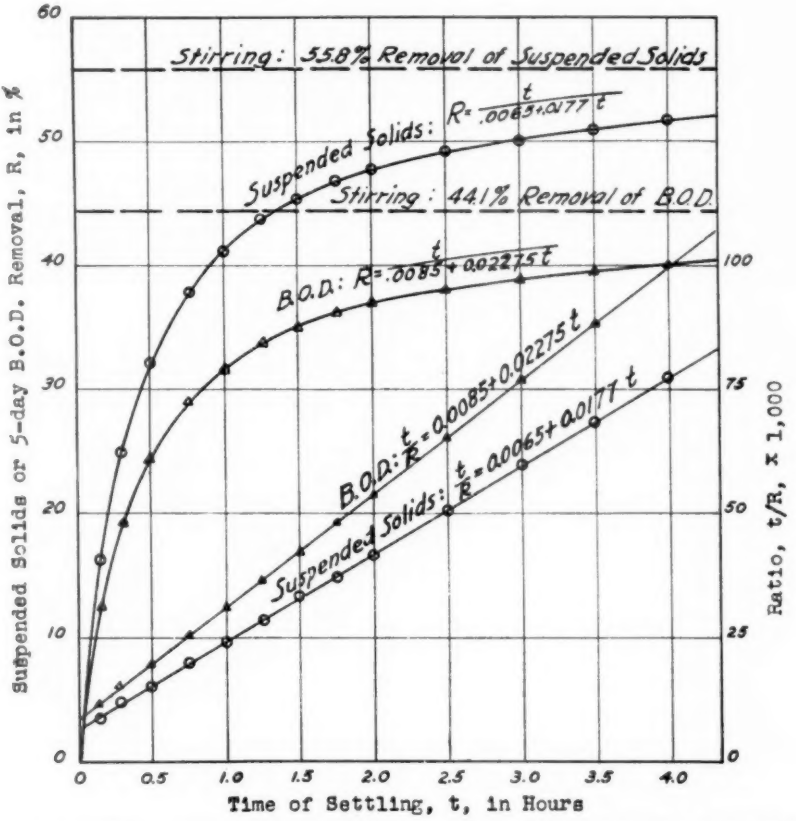

FIGURE 1.—Comparative removals of suspended solids and 5-day B.O.D. by plain sedimentation and by 15-min. stirring in 200-ml. jars for domestic sewage with average initial suspended solids of 340 p.p.m. and B.O.D. of 320 p.p.m.

for removal of suspended material effected by 15 min. of plain stirring followed by 20 min. of quiescence. The significance of this relationship is that under laboratory conditions, 15 min. of plain stirring followed by 20 min. of quiescent settling effects the same removal as plain sedimentation over an indefinite period of time.

This relationship suggests the feasibility of a new standard test procedure for settleable solids, or "total settleable solids," which would employ a 15-min. stirring period followed by a 20-min. settling period instead of plain settling for 2 hr. in an Imhoff cone. The test could be made by stirring a 1-l. sample in a liter beaker, then transferring the stirred sample to an Imhoff cone for the 20-min. period of settling. A specially designed mixing jar with a graduated conical bottom would be preferable, as it would eliminate the need for a transfer.

The principal advantage of this new procedure is its elimination of the delicate and erratic nature of the present procedure. The stirring process, by

flocculating or coagulating all of the settleable colloids, produces relatively large and dense particles, which settle out rapidly and promptly to form a compact bottom mass. There is practically no error due to adherence of the settling particles to the glass walls of the cone, or to void spaces in the mass of bottom solids, and the result is not dependent on subjective tapping of the cone. Also, the time required for making the test is reduced. The result obtained has an absolute significance in representing the portion of the suspended particles that can be removed by ultimate or 100 per cent primary treatment. In the standard test, the result obtained (the 2-hr. reading) has an uncertain relationship to the ultimate primary treatment removal.

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REDUCING CONSTRUCTION COSTS *

By Robert B. Rothschild, Jr.

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Construction costs are coming down —and it's about time. Certainly, everyone is pleased, engineers and contractors alike, and especially the general public. Instead of engineers' estimates being too low, they are now too high. Probably today's costs for residential construction are 25 per cent less than in September, 1948, and construction costs for sewage and water plants are 15 to 20 per cent less. The reduction is due to a combination of many factors—reduced material prices, increased efficiency and productiveness of labor, and more competition amongst subcontractors and general contractors. All of these are natural economic causes and are usually beyond the control of individual engineers or contractors.

There are, however, other factors which contribute materially to the cost of construction—namely, the wording of a unit price bid form, the design or plans, and the specification itself. These subjects will be touched on briefly with the hope that the criticism, if any, is constructive.

Unit Price Bid Form

The wording and the manner of presenting a bid form have an important significance in determining the ultimate cost of the job to the owner and in assuring a reasonable profit to the contractor. When a contractor is preparing a bid on a job which is obviously very risky he naturally will try to figure on the safe side. Often, provision is made in the bid for contingencies to take care of construction difficulties that may be expected, but which in all probability will not occur. Thus, when a specification is set up with a bid form which tends to throw the burden of unforeseen elements on the contractor, the chances are that the owner will pay not only for the contingencies which do occur, but also for some which do not. The intelligent solution would seem to be to set up a manner of bidding that will allow the contractor to be paid just for the contingencies that do occur and can be evaluated, but not for those that are purely problematic.

On the other hand, if specifications are written intentionally or unintentionally to place unforeseen and not obvious hazards on the shoulders of the innocent contractor, he will consequently fail to consider costs of contingencies, with the result that he will suffer a serious loss. When unforeseeable risks are eliminated from the contract by a proper bid form the contractor is saved from these pitfalls.

It has been a sad fact in the construction business that everybody concerned suffers when a contractor bids too low on a job. The contractor will unconsciously take unnecessary risks, which may prove very costly in life and dollars, and he may even cut down on the quality of his work. If he loses too much money the bonding company has to take over the job, the progress of the work is greatly delayed, and the engineer and the owner are put to a lot of unnecessary trouble and expense.

The unit bid form is the most expedient way of arriving at a solution on heavy construction and other types of projects where the hazards are of great consequence. However, in the past many unit bid forms have lost sight of their purpose and have become

* Presented at 1949 Annual Meeting, California Sewage Works Association; Stockton, Calif.; May 19–21, 1949.

merely a mathematical nightmare for the contractor, instead of a means of reducing his hazards.

On the other hand, unit bid forms should be set up in such a way as to discourage the unbalancing of bids. If this is not done the lowest bid based on the assumed bid units may prove to be the most expensive when the final certificate is issued and the final quantities are settled. A brief reference to one example of unit price bid forms, namely, pile driving, will suffice to illustrate this point.

The total cost of furnishing and driving piles for any given job is, at best, a mere estimate. Therefore, a bid form for pile driving should be set up in such a way as to reduce the hazards of bidding to a minimum. Two bad examples of pile bid set-ups are as follows:

(1) The lump sum bid, in the case where the pile lengths are specified, often works against the best interests of the owner in that the specified lengths may not be satisfactory for the job. When the lengths are not specified, unwarranted responsibility is thrown on the contractor, even when pile test data have been made available.

(2) The unit bid price per linear foot for furnishing and driving piles does not take into consideration the fact that the number of piles to be driven may remain constant while the total linear feet of piles varies. This form encourages extreme unbalancing of bids by the contractor in order to protect his bid, a device which may work against the best interests of the owner and more often will prove very expensive to the contractor.

In a pile-driving specification it is well for the engineer to specify the number, length, and location of certain test piles to be driven with a required height of driver and size of hammer. After the contractor has driven the test piles, the engineer should determine the length of piles he wants for the job.

It is best to request bids only on those items the quantity of which can be estimated in advance of the bidding with reasonable accuracy. The quantity of such items as pile splices is usually very uncertain, and, inasmuch as the unit price varies greatly with the quantity, they should be paid for at an agreed price or at cost plus.

A suggested unit bid set-up for the example selected is as follows:

1. Furnishing and driving test piles will be paid for at a lump sum. (Quantity, location, and length of test piles will be specified.)
2. Driving of piles will be paid for at the unit price per pile.
3. Furnishing of timber piles will be paid for at the price per linear foot of piles. Pay quantities will be the total length as ordered by the engineer and delivered to the job, with the usual allowance of 2 ft. over or under any specified length.
4. Load tests will be paid for at a lump sum. (Number and size of tests will be as specified.)
5. Pile splices, if required, will be paid for on a cost plus basis, or at an agreed price.
6. Pile shoes will be paid for at the unit price for each.

Where bid quantities are given for unit items of work, such quantities should be as nearly accurate as possible, and the responsibility for their accuracy lies with the engineer. In case of an appreciable error, provision should be made to adjust the contract unit prices to conform with the change in quantity. An example of this would be a case where a unit price was given for an item of structural concrete in place, for instance, as in a bridge job. Generally this unit price for structural concrete includes forms, falsework, finish, plant set-up, concrete, overhead and profit. If there is an appreciable variation in the actual quan-

tity of concrete, it can readily be seen that the result would be unfair to the owner in case of an increase in quantities, and quite unfair to the contractor if the quantities are decreased, as certain fixed charges are included in the unit cost.

Plans

Plans should be clear, well dimensioned, and well indexed. There should be plenty of cross sections, and these sections should be easy to find. A man on the job can waste much time and make numerous mistakes because the plans are not clear or have insufficient details and dimensions.

A problem that presents itself in the field today is the dearth of high-calibre skilled and unskilled workmen. In order to cope with this situation it is advisable to simplify structures as much as is practical. In designing a concrete structure, whether it be a sewage or water treatment plant, a bridge, or a building, it is well from a standpoint of economy to have as much repetition in design as possible. Walls that lend themselves to panel forms will usually save form lumber and labor. When there are a number of beams of the same concrete size the cost will be materially less, even though extra concrete must be used to standardize the size. A wise practice in designing concrete structures is to keep most of the concrete beams to widths that will accommodate the commercial surfaced lumber sizes for soffits, such as 5½, 7½, 9½, or 11½ in.

One detail in concrete construction which is expensive to frame in forms and should be avoided whenever possible is to have ornamental concrete protrude from the surface of a wall (for example, a window sill, a lip around an opening, or a concrete ornament). These items, if necessary, should be connected or plastered to the wall after the wall is constructed. It is always costly to frame out from a wall, much cheaper to frame inwards.

Specifications

Specifications, in general, should be definite as to intent and should not leave any doubt or uncertainty in the mind of the engineer or contractor. They should be fair to both parties so as to protect the rights of either side.

Some examples of clauses which are used occasionally, but which tend to raise the bid on a job, are as follows:

"The Engineer may change the line and grade and dimensions of any structure or pipe line at any time. The Contractor shall make no claim for extras on account of natural conditions in the new location being different from what they would have been in the location shown on the drawings, or on account of the amount of any item, or the expense of construction being greater than such cost would have been if the location had not been changed."

Very often it is specified that the contractor has no recourse for damages against the owner for delays occasioned by the owner. In some cases it is specified that the contractor shall pay for the inspection during periods of delays caused by the owner. A fair and appropriate clause is:

"If either party to this Contract should suffer damage in any manner because of any wrongful act or neglect of the other party or of anyone employed by him, he shall be reimbursed by the other party for such damage."

Some other examples of unfair clauses are:

Drawings and Specifications: ". . . Should anything afterwards appear to have been omitted in either or both, but which is implied as necessary for the thorough and proper construction of the work or to conform to all State, City, and Sanitary District laws, rules, and regulations shall be furnished and executed by the Contractor the same as if shown on drawings or described in specifications."

Concrete Work: ". . . Moreover, the Architect may order such changes in grading and/or proportions as, in

his opinion, are necessary to carry out the intent of the plans and specifications, and these changes shall be made at the Contractor's expense."

In conclusion, it might be said that bid forms, plans, and specifications which are so designed or written as to protect both the engineer and the contractor, and which are clear, simple, and well organized will, in the long run, result in a finished job at the lowest cost.

FEDERAL WATER POLLUTION STUDY FUNDS

Provisional allotments totalling $850,000 to states, territories, and the District of Columbia for grants to study water pollution resulting from industrial wastes were announced recently by the Federal Security Administration, which at the same time announced the agencies officially designated to represent the states, territories, and the District of Columbia in administration of the Water Pollution Control Act, under which the funds were appropriated. The sum is in addition to an allotment of $1,200,000 to the Public Health Service for operation, research, administration, and planning, and $150,000 still to be allocated to interstate agencies for special studies of national or regional importance.

The amounts allotted are:

State	Allotment	Agency
Alabama	$20,010	Dept. of Health
Alaska	9,212	Dept. of Health
Arizona	10,388	Dept. of Health
Arkansas	17,396	Water Poll. Comm.
California	27,370	Dept. of Health
Colorado	11,385	Dept. of Health
Connecticut	12,296	Water Commission
Delaware	9,079	Water Poll. Comm.
Dist. of Col.	10,304	Health Dept.
Florida	15,198	Board of Health
Georgia	20,386	Dept. of Health
Hawaii	9,978	Dept. of Health
Idaho	9,969	Dept. of Health
Illinois	26,078	San. Water Board
Indiana	18,321	Stream Poll. Board
Iowa	15,999	Dept. of Health
Kansas	13,697	Board of Health
Kentucky	19,698	Dept. of Health
Louisiana	17,805	Stream Cont. Comm.
Maine	10,941	Dept. of Health
Maryland	13,216	Water Poll. Comm.
Massachusetts	18,780	Dept. of Health
Michigan	22,310	Water Res. Comm.
Minnesota	16,982	Water Poll. Comm.
Mississippi	19,637	Board of Health
Missouri	19,559	Dept. of Health
Montana	9,619	Board of Health
Nebraska	$12,021	Dept. of Health
Nevada	8,758	Dept. of Health
New Hampshire	10,123	Water Poll. Comm.
New Jersey	18,085	Dept. of Health
New Mexico	10,372	Dept. of Health
New York	35,326	Dept. of Health
N. Carolina	23,178	Board of Health
North Dakota	9,842	Dept. of Health
Ohio	25,780	Dept. of Health
Oklahoma	16,723	Health Dept.
Oregon	12,208	Board of Health
Pennsylvania	34,227	San. Water Board
Puerto Rico	19,919	Water Cont. Comm.
Rhode Island	10,127	Dept. of Health
S. Carolina	16,978	Board of Health
South Dakota	10,069	Water Poll. Comm.
Tennessee	19,737	Stream Poll. Board
Texas	30,197	Dept. of Health
Utah	10,239	Dept. of Health
Vermont	9,559	Water Cons. Board
Virginia	17,774	Water Cont. Board
Virgin Is.	8,645	Dept. of Health
Washington	13,473	Poll. Cont. Comm.
W. Virginia	15,039	Water Comm.
Wisconsin	16,808	Water Poll. Comm.
Wyoming	9,180	Dept. of Health

Industrial Wastes

A NOVEL HIGH RATE ANAEROBIC WASTE TREATMENT SYSTEM [1]

By Harry W. Gehm and Philip F. Morgan [2]

Technical Advisor and Former Chief Development Engineer, respectively, National Council for Stream Improvement of the Pulp, Paper and Paperboard Industries, New York, N. Y.

Technical difficulties, together with the costs involved for oxidizing aerobically trade wastes relatively high in dissolved organic matter, have led to considerable interest and development of high rate anaerobic digestion. Originally developed by Boroff and Buswell and Le Bosquet (1) for distillery wastes, considerable attention has and is being given to its application to other wastes and to perfecting the technique for applying it. It has been found to be a most efficient method for obtaining high B.O.D. reductions at relatively low cost if the waste treated has, or can be conditioned to have certain chemical and physical characteristics. The major of these characteristics are:

1. Has an initial B.O.D. in excess of 500 p.p.m.;
2. Has a nitrogen-carbon ratio of at least 1 to 20;
3. Has a high buffer capacity in relation to organic substances that form volatile acids on decomposition;
4. Is relatively free of settleable suspended matter;
5. Contains organic matter, the major part of which is readily decomposable and the type varied;
6. Has a low sulfur content (not essential, but advantageous); and
7. Is in the neutral pH range and does not contain inhibiting substances.

After settling to remove the coarse suspended matter strawboard waste was found to answer all of these qualifications, as it can be obtained in a concentration range of from 600 to 3,500 p.p.m. B.O.D. (depending on mill practice), contains sufficient nitrogen, is high in buffer capacity (because the straw was cooked in alkali), is low in sulfur, is free of inhibiting substances (although the pH was quite high) and was shown by Kessener (2) to be digestible at low rates. An added advantage was that it could be obtained relatively warm. It was concluded from these observations that a comprehensive study of this process as applied to strawboard waste might prove fruitful. Hence, laboratory studies were initiated by Bloodgood (3) (4) as a part of the National Council for Stream Improvement strawboard waste project at Purdue University.

Employing a digester of 3,500-ml. capacity, maintained at constant temperature and agitated continuously, experiments were started employing sludge collected from an old strawboard lagoon as seed. These continued for the better part of a year, during which an attempt was made to establish and evaluate the variables attending this process. From this work the following conclusions were drawn:

[1] Presented at Twenty-first Annual Meeting, New York State Sewage Works Association, New York City, January 21, 1949.

[2] Now Associate Professor, College of Engineering, University of Iowa, Iowa City, Iowa.

1. Settled strawboard waste could be digested at high rates between 25° and 37° C., the highest temperature producing optimum results.
2. No difficulties were experienced from the high initial pH, and buffers were present in sufficient quantity so that supplemental alkali was not needed.
3. B.O.D. reductions in excess of 90 per cent were obtainable under ideal conditions.
4. Gas produced was high in methane and low in H_2S.
5. The seed sludge did not increase in volume appreciably, hence, would not represent a disposal problem.
6. Intermittent operation or loading variations did not affect the process.
7. Throughout a year's operation no diminution in effectiveness of the seed was observed.
8. Agitation was found necessary to produce anywhere near the best rate of digestion.
9. Seed sludge settled rapidly and completely from the liquor when agitation was stopped.

Inasmuch as the laboratory studies appeared so satisfactory, the next stage was to carry this process into pilot plant development for the purpose of determining what rates of waste reduction could be obtained under conditions of continuous operation and what would be the best design and operating techniques. This necessitated, first, a decision as to whether to operate a small pilot to gain experience with continuous operation for the purpose of providing design data for a larger unit or to immediately design and operate a pilot of sufficient size that the results could be translated into full-scale operation. The consistency of the laboratory results and the amount of back-

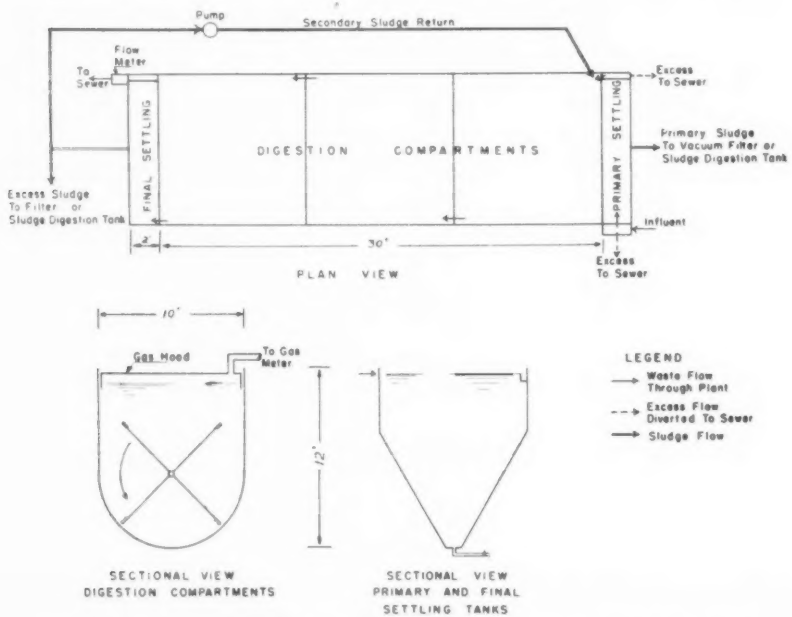

FIGURE 1.—Layout of pilot plant for anaerobic digestion of strawboard wastes.

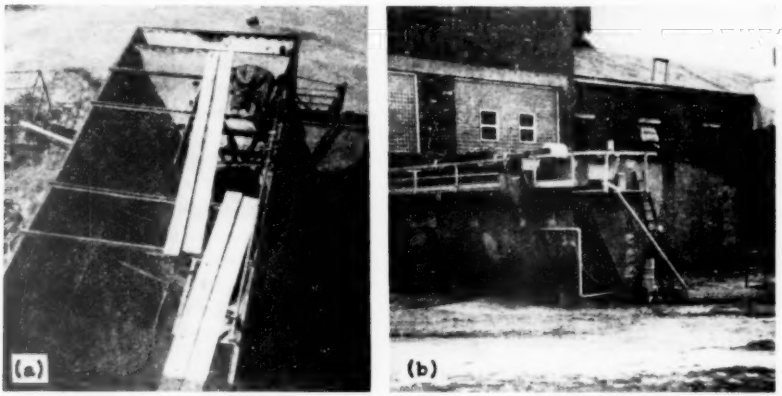

FIGURE 2.—Strawboard wastes digestion pilot plant: (a) during construction; (b) as completed.

ground information with other wastes led to a choice of the latter alternative.

Prior to proceeding with design of the large pilot plant, a study was made of existing equipment employed in this process, and operating methods and problems were discussed with those experienced in large scale operations. The authors are indebted to Mr. Eugene Trubnick of the Anheuser-Busch Company, Dr. Willem Rudolfs, Dr. F. W. Mohlman, and Prof. D. E. Bloodgood for their able advice and assistance.

Analysis of the information collected led to the conclusion that the major difficulty met with was periodic declines in efficiency. This was thought by some to be due to loss of activity on the part of the seed sludge. It gradually gains in mineral content, and the resulting loss in organic matter was believed to influence the organisms present. However, others believed this effect to result from loss of sludge, which can readily take place unobserved from conventional systems. It is now considered good practice to place a clarifier in the digester effluent line to act as a catch-all for escaping sludge, so that it can be returned to the digester.

Although lacking sufficient experience to form an opinion as to which of the theories as to the cause of attenuation applies, the laboratory experiments did indicate the necessity for retaining as much of the seed sludge in the system as possible. It was believed also, that the organic content, as well as progressive small mechanical losses, could be compensated for by the periodical addition of primary sludge. On examination of the conventional system it appeared that, after devoting a comparatively large proportion of the digester to separating treated waste from seed sludge, provision of a secondary clarifier was a duplication of effort, irrespective of the fact that there are economic advantages to carrying on the entire process in a single unit. Also, in achieving the latter it is necessary to allocate more cubic capacity to clarification than is required by a separate unit.

Another factor under consideration was the single unit method of diffusing the waste through a suspended blanket of seed sludge. Although unquestionably good sludge-liquid contact can be obtained in this manner, direct agitation is a more dependable manner of obtaining the maximum degree of contact and an equalization in the liquor whereby its concentration is maintained at a more even level. Again, be-

cause agitation yielded excellent results in the laboratory tests it seemed worthwhile providing for it in the final design.

In line with the foregoing reasoning it was decided that a high rate anaerobic system with a flow diagram similar to the activated sludge system might prove more effective than previous designs. In addition, it was apparent that better control would be possible, as the sludge-liquor ratio could be maintained constant and a sludge inventory readily kept. In carrying out this design an agitated digester of rectangular design was built, followed by a clarifier and means for returning sludge continuously. The general layout of this unit is shown in Figure 1.

It first had been thought best to build the pilot of wood, using a paper mill stock chest for the digester body. However, it was found that it could be fabricated of steel at somewhat lower cost and in using steel, attachment of accessory equipment presented less of a problem. Figure 2 shows the pilot

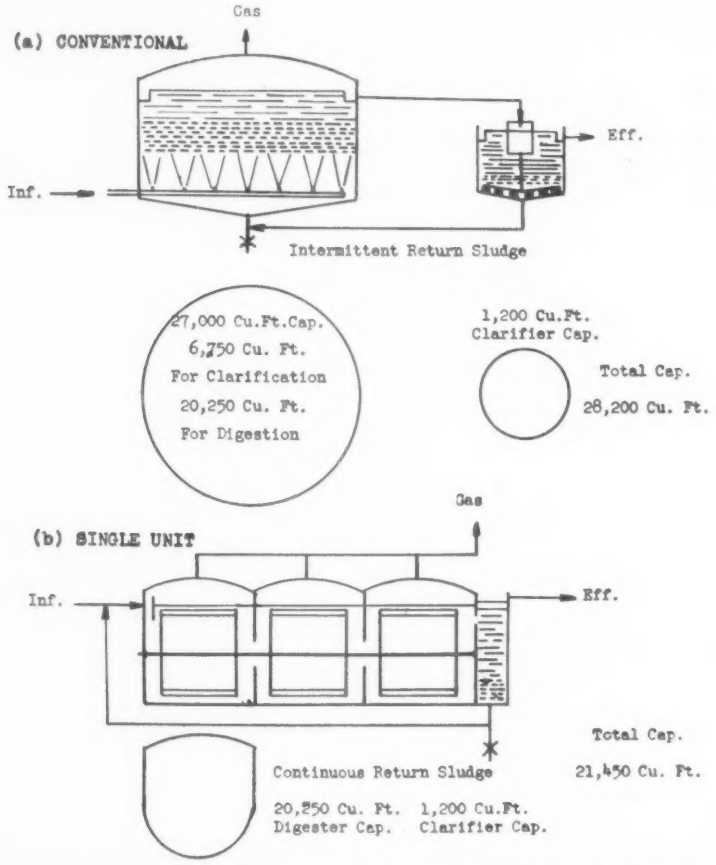

FIGURE 3.—Comparison of units required for treating 200,000 g.p.d. of strawboard wastes with 48-hr. waste detention time.

plant during erection and as completed.

The digester has a total capacity of 2,600 cu. ft. and is divided by baffles into three sections, each of which has a separate floating gas collector and a separate agitator driven from the central shaft. Each gas collector is metered separately for experimental reasons, and provision is made for continuous sludge return. Although the temperature of the waste entering the pilot is sufficiently high to permit the optimum digestion rate, the digester contents were found to cool rapidly despite insulation with straw bales piled around the tank. The high loss was due to continuous agitation of the tank contents against the cold steel walls. Installation of a unit air heater between the bales under the tank now maintains satisfactory temperature conditions.

A comparison of this system with an efficient conventional layout is shown in Figure 3, in which the capacity requirements are set forth on the basis of digester effectiveness similar to the present installation per pound of B.O.D. removed at high loadings. Examination of Figure 3 reveals that 21,450 cu. ft. of capacity was required by the new unit, as compared to 28,200 cu. ft. for the conventional system, allowing the upper quarter of the digester for clarification. It is believed, however, that the new system is likely to allow lower digester capacity for a given loading than that shown. This it must do to justify the higher construction and operating power costs that it involves. The pilot plant has been put in operation and the starting difficulties have been resolved. Loading tests designed to provide the answer as to the practicability of this system are proceeding.

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DISCUSSION

By Eugene H. Trubnick

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As anaerobic digestion is being applied to the treatment of an ever increasing variety of soluble organic industrial wastes, the view (1) that wastes containing less than 1 per cent organic solids cannot be economically treated by digestion is losing validity. Digestion of wastes with as low a concentration as 1,000 p.p.m. solids and 500 p.p.m. B.O.D. (2) is now feasible, especially if the solids in the waste are predominantly dissolved and colloidal.

In treating a soluble material by contact with an insoluble seed sludge, involving reactions which occur at the surface of the organism-rich sludge particles, it is imperative that thorough and intimate contact be maintained between the liquid and the sludge particles. This fact has been demonstrated in the treatment of yeast wastes (3), where increased contact achieved by intermittent agitation resulted in average increases of 30 per cent in B.O.D. reduction and 26 per cent in gas production. Heukelekian (4) has shown that shaking a digesting sludge mixture after each day's dosage of

fresh solids provided sufficient mixing with the seed to result in a 28 per cent increase in gas production. Continuous agitation, providing thorough contact throughout the reaction, should result in even greater improvement in digestion.

The contact between sludge and liquid may be provided for by any of several methods, depending on the characteristics of the material to be treated. In the case of the yeast wastes, because the sludge, although well compacted, was of fine particle size and was slow in settling, contact was achieved by an up-flow process introducing the liquid at the bottom of the digestion tanks and allowing it to flow upward slowly to a peripheral overflow weir. Escaped sludge was settled in a clarifier and returned to the digesters. The ebullition of the evolved gas provided a further degree of mixing. In the case of strawboard wastes, with a fast settling sludge, mechanical agitation with subsequent sedimentation should offer very effective mixing.

Not only does agitation improve B.O.D. reduction and increase gas production, but it also accelerates the rate of gasification and releases the gas from the mixture. Again referring to yeast wastes, with which the author has had "thorough and intimate contact," it was found that while a digestion mixture proceeding under quiescent conditions evolved 55 per cent of its 24-hr. gas production in 10 hr. when peak gasification occurred, an agitated sample of the same mixture gasified at peak rate in 3 hr. and evolved 55 per cent of the 24-hr. gas production in 4 hr. [see Figure 4, THIS JOURNAL, **21**, 1, 103 (Jan., 1949)].

Complete removal of the gas from the digestion mixture will not only provide maximum quantities of available gas for heating or other purposes, but will avoid any possible nuisances or hazards from gas evolving subsequently from the digester effluent.

The performance of the digester unit will depend to a great extent on the ratio of sludge to liquid. A sludge deficiency obviously will result in deterioration of the digestion process through depletion of the active flora; an excess of sludge will result in expansion and subsequent sludge losses, thus producing a mixture difficult to handle mechanically. Although the effective sludge-liquid ratio may cover a wide range, there are definite limits to this range, and the amount of sludge present in the tanks should be known at all times so that sludge withdrawals can be made whenever necessary. The process described by Dr. Gehm and Mr. Morgan provides for a simple and accurate method of determining sludge content as a means of control and assures uniform operating conditions throughout the digester.

The anaerobic digestion of soluble organic wastes can be accomplished with very short detention periods—a matter of days or even hours—and, in fact, has been done on pilot plant scale with such materials as yeast wastes (5) in 1.5 days and on chewing gum wastes in 5 days (6). Many other examples could be cited.

Rankin (7), in a discussion of sewage sludge digestion, has pointed out the relation between detention time and performance, and has proposed the detention method as a yardstick for evaluating digester performance.

Performance of digesters in the treatment of soluble organic wastes is likewise a function of detention period (3). As the detention time is increased all indices of purification—gas production, B.O.D. reduction, and solids destruction—show a proportionate increase [see Figure 2, THIS JOURNAL, **21**, 1, 101 (Jan., 1949)]. If the composition and volume of a given waste remain fairly constant from day to day, the detention period may be considered a reflection of loading. In fact, studies

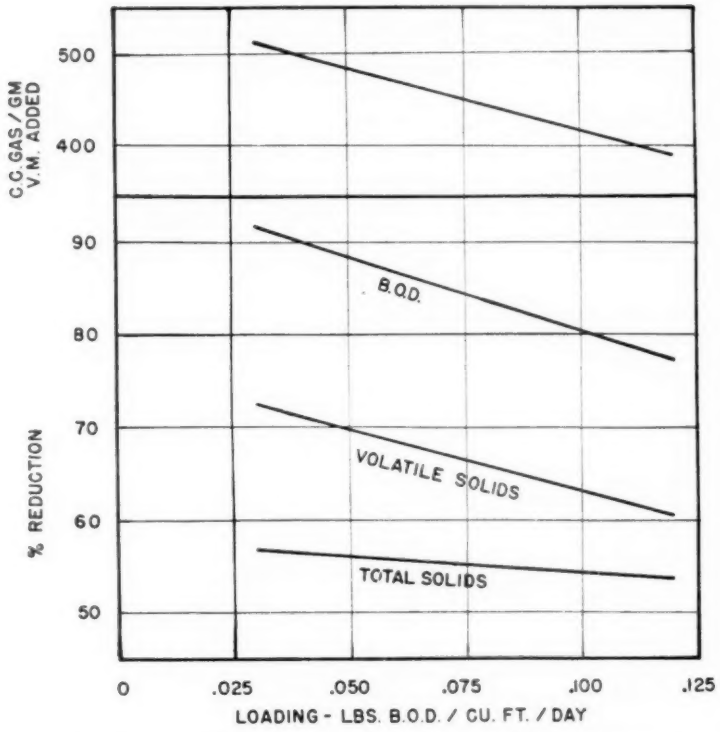

FIGURE 1.—Relationship between loading and digester efficiency.

conducted with yeast wastes (5) have indicated that loading is an even more accurate yardstick of performance than is detention period. A given loading resulted in a definite B.O.D. reduction, regardless whether the load was applied as a 2,000-p.p.m. material for 2 days, a 3,000 p.p.m. material for 3 days, or a 4,000 p.p.m. material for 4 days. In other words, the amount of work performed by the digester is a direct function of the load applied to it.

Furthermore, a relationship was established between loading and digester efficiency (Figure 1). In general, at increased loadings the digester operated at decreased efficiency, no matter what index of efficiency is considered—the rate of gas production, B.O.D. removal, or destruction of total or volatile solids. Loadings are expressed in Figure 1 in terms of pounds of B.O.D. per cubic foot of digester capacity per day. This unit was chosen because B.O.D. reduction is the aim sought for in the digestion of soluble organic industrial wastes, and also in order that the digestion process could be compared with trickling filter treatment.

Once the relationship between loading and performance is established for the digestion of a particular soluble organic material, this relationship can be used as a basis for design of a treatment plant and for prediction of results to be expected under various operating conditions. The use of B.O.D. loading and B.O.D. reduction as yard-

sticks may be a bit slow and cumbersome for day-to-day operational control, but any of the other indices—gas production, or destruction of volatile solids—may be used as the daily index of performance.

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BALTIMORE SUIT DECREE

In a suit filed July 18, 1949, against the Mayor and City Council of Baltimore, Md., the Back River Civic Improvement Association and a group of property owners brought action for an abatement of the pollution caused by the city's Back River sewage disposal plant and asking that the municipality be forced to dredge the river to remove large quantities of sludge claimed to have been deposited in the river from the plant. Extensive expert testimony was offered on behalf of both the complainants and the respondents.

The main points covered in the decree, handed down in early August by Circuit Court No. 2 of Baltimore, are that the city shall:

1. Seal all plant by-passes by October 1, 1950.
2. Equip the entire acreage of the existing trickling filter beds with rotary distributors.
3. Install mechanical sludge removal equipment in the humus tanks, and meanwhile clean the tanks manually at least weekly.
4. Restore original wall heights to prevent sewage overflows to Back River.
5. Repair the breaks in the present outfall conduits.
6. Install an additional 25-m.g.d. primary settling tank, and plan for another to be in service before the plant is again overloaded.
7. Install sludge drying equipment now planned and then proceed to clean up the plant.
8. Reduce odors, particularly from the old settling tanks and sludge dumps on the plant property.
9. Undertake studies of the activated sludge process for future additions to the plant capacity, the disposal of effluent to the Patapsco River, and the apportionment of sewage treatment costs within the plant's tributary area.
10. Not be required to dredge the Back River.

CHARACTER AND TREATMENT OF SOLUBLE OIL WASTES

By T. R. Haseltine

Partner, The Chester Engineers, Pittsburgh, Pa.

In this day of accelerated activity in the abatement of stream pollution designing engineers are constantly faced with the problem of prescribing treatment for some waste, unfamiliar to them, about which little or nothing has been published. Soluble oil wastes are one of these poorly understood wastes. In the broad national picture of stream pollution these wastes may play a relatively minor role, but in an area such as the Pittsburgh district they are frequently encountered and must be treated if state requirements are to be met. In Pennsylvania a limit of 30 p.p.m. has been set as the maximum permissible amount of oil in any waste discharged to the waters of the Commonwealth. Frequently, the volume of oily wastes discharged from a given industrial establishment may be relatively small and the volume of comparatively clean spent cooling water may be so high that the oil content of the combined discharge will be less than the permissible maximum, even though no treatment is provided for the oily wastes. The Pennsylvania Department of Health has ruled that, even in such cases, any oily wastes practical of segregation must be separated from the cooling water and treated prior to discharge. This means, in most cases, that soluble oil wastes must be treated even though their volume may be relatively small.

Soluble oil wastes are emulsions of oil in water and, as such, are not amenable to treatment by gravity separation processes alone, such as are commonly used for other oily wastes. To the writer's knowledge, the recent article by Eldridge and Purdy (1) is the first to deal with the treatment of soluble oil wastes and so is a very valuable contribution to the literature. However, in the writer's opinion, that paper is subject to criticism because it tends to over-simplify both the variable character of soluble oil wastes and the problem of treating them. This paper is intended to supplement that article and thus, it is hoped, increase its value to the profession.

The writer was first faced with the problem of devising a treatment for soluble oil wastes early in 1946, and has encountered the problem several times since then. Because personal experience, the available literature, and replies to questionnaires mailed to several manufacturers of soluble oils offered no satisfactory solution to the problem, rather extensive laboratory experiments were carried out. As a result of the studies, plans have been prepared for soluble oil treatment at three plants. To date, however, none of those facilities has been constructed. Inasmuch as the laboratory results have not been confirmed on even a pilot plant scale, there has been a tendency to hesitate in publishing them. However, the article by Eldridge and Purdy (1) was also based entirely on laboratory tests, and as the present findings tend to confirm some of their conclusions and conflict with others, it is felt that the results presented herein may be a help to the profession.

Character of Soluble Oils

Despite their name, soluble oils do not go into true solution. In appearance most of them look like other dark heavy oils, but on being mixed with water they form white, stable emulsions. Eldridge and Purdy (1) state

". . . in general, soluble oils are homogeneous compositions containing mineral oil, pine oil, or other hydrocarbon oils; emulsifying agents such as potassium or sodium soaps, or sulfonated oils; and an indeterminate amount of water."

The federal specifications (2) for soluble oil limit its water content to a maximum of 10 per cent and its ash content to 3.5 per cent, but make no mention of other components of the oil. Manufacturers of some soluble oils advise that their products contain less than 1 per cent moisture and less than 1.5 per cent ash.

Brady (3) defines and describes soluble oils as follows:

"Oils made soluble by treatment with sodium hydroxide or other alkali, either by direct mixture or by the addition of soaps to the oil. Oils thus treated emulsify readily because of the formation of sodium oleate and sodium palmitate and are mixed with water for use in pumping over the work being machined in rapid-production machines. The presence of about 1 per cent of sulphur is important. Sulphonated lard oil is used to bring up the sulphur content. Pine oil or oil of sassafras is added to improve the odor. Cresol is added for disinfecting. Rosin or rosin oil is added to form sodium resinate to improve the cutting qualities. A typical oil mixture is 40 gal. of water, 10 of lard oil, 2.5 lb. of soda ash, and 10 oz. of borax. Soda water, used as a substitute for soluble oils for cooling metal-cutting tools is made with 100 gal. of water, 18.5 lb. of soda ash, and 15.5 lb. of soap. Soluble oils are used mainly for keeping the work and cutters cool, but they also exert a lubricating action between the cutting edge of the tool and the work, thus decreasing the friction of cutting. In machines having hardened and ground steel spindles, the soluble oils are also used to lubricate the bearings because of the facility of flow and their cooling action."

The formulas for most soluble oils have been developed by research in the manufacturers' laboratories and so, in general, the manufacturers are reluctant to reveal the exact composition of their products. In some instances, even their own salesmen are not fully informed in this respect. Some concerns manufacture only one grade of soluble oil, which is recommended for a wide variety of uses. Other concerns make several different grades, each of which is sold for a specific use.

The soluble oils of some manufacturers, like Sun Oil Company and American Oil Company, contain no animal or vegetable material. The products contain only mineral oil and sulphonated petroleum derivatives. American 2601 soluble oil is composed of 20 per cent mineral oil and 80 per cent sulphonates. In these oils the sulphonates act as the emulsifying agent, as no soaps are present. Sutheim (4) states that sulphonates are superior to soaps as emulsifying agents in the presence of calcium compounds. Presumably, therefore, hard water emulsions of soluble oils containing sulphonates are more difficult to break than are those of oils containing soap.

There is a wide variation in the quantity of soap used in those oils which utilize it as the emulsifying agent. Manufacturers say that some oils contain as little as 5 per cent soap, whereas others contain as much as 18 per cent. Rape oil is added to some soluble oils because of its tendency to increase the stability of the emulsions. Since rape seed has become so expensive and difficult to obtain, synthetic compounds having a similar effect have been developed.

Obviously, soluble oils containing a high proportion of animal or vegetable oils are more likely to become rancid than those containing only petroleum products. Therefore, they are the ones that contain such preservatives as cresol and "perfumes" like pine oil and oil of sassafras.

Some oils contain "E P additives," which are understood to be sulphur or phosphorus compounds added to improve either the lubricating property

of the oil, or the permanence of the emulsions under extreme pressures.

Many soluble oils are not manufactured by the large oil refinery companies, but instead are prepared by small chemical or specialty companies. One product, Cimcool Cutting Compound, differs greatly from most soluble oils. It resembles a pink paint in appearance and contains only 10 per cent mineral oil, 40 per cent water and 50 per cent of other compounds. After mixing with water, a small amount of a special "conditioner," an oil-like substance, is added as a rust preventative. The mixture retains the pink opaque appearance of the original compound.

Although the foregoing data are rather indefinite, they serve to indicate the wide variations in different soluble oils. As further evidence of this fact, it was found that a single factory or mill might be using several different oils, each obtained from a different manufacturer, and each used for a different purpose.

Character of Soluble Oil Wastes

Emulsions of soluble oil in water are widely used as a coolant and lubricant in machining operations. The ratio of oil to water varies with the type of work. The Sun Oil Company (5) suggests that their Sunoco Emulsifying Oil be used in the following proportions:

1 part oil to 10 of water for bolt cutting, nut tapping, etc.
1 part oil to 15 water for machining high carbon and alloy steels.
1 part oil to 20 of water for machining low carbon steels.
1 part oil to 30 to 50 parts water for grinding.

Eldridge and Purdy (1) state that in some instances these cutting emulsions are used only once and then discharged to the sewer. In the work described in this paper, however, that condition has never been encountered. In some cases, each individual machine had its own reservoir and coolant circulating pump; in others a number of machines would be supplied with emulsion pumped to them under pressure from a single reservoir. After passing through the machines the coolant flowed back to the reservoirs, which ranged in capacity from 5 gal. on a single machine to 2,400 gal. serving a larger number of machines. Normally, these reservoirs are cleaned out from 1 to 3 times a year. However, one case was found where a 1,000-gal. reservoir was cleaned out every 4 or 5 weeks because the gravity returns were simply floor trenches covered with loosely fitting steel plates.

In all instances, during the reservoir cleaning operations the spent emulsions were diluted with considerable quantities of wash water. Where no direct connection existed between the reservoir and the sewer, the volume of wash water used ranged from 1 to 3 times the volume of emulsion dumped. Obviously, this wash water became mixed with the original emulsion so that, in effect, the waste to be treated, instead of averaging say 1,000 gal. of 10 per cent oil emulsion, might average as much as 4,000 gal. of 2.5 per cent oil emulsion. It seems probable that if there was a direct connection from the reservoir to the sewer, the quantity of wash water, and hence the dilution, might be considerably greater.

Make-up water and soluble oil are frequently added to reservoirs to replace the emulsion "dragged out" on cuttings and products leaving the machines. Drainage from cuttings storage bins is a prevalent source of routine flows of soluble oil wastes. If these storage areas are exposed to the weather, the emulsion will be diluted with storm water.

In screw and bolt manufacture, at least, the bolts, nuts, etc., go to "washing machines" after being machined. There the articles to be washed are

dumped onto a conveyor that carries them through the washing machine in which they are thoroughly washed by sprays of hot soluble oil emulsion. The emulsion, stored in a tank below the conveyor and kept at boiling temperature by means of steam, is continuously pumped from the tank, through the sprays, and falls back into the tank carrying any dirt or cuttings with it. From time to time during the day water and soluble oil are added to the tank to make up for the losses by drippage, spillage, and drag out. An 11-day check at one large washing machine showed that an average of 850 gal. of water and 4 gal. of soluble oil were added to the machine each 16-hr. day. This would indicate that washing machine wastes contain something less than 0.5 per cent oil. Actually, their oil content is considerably higher, as the products entering the washing machine are usually covered with either an emulsion of higher oil content or, in some cases, a true cutting oil instead of an emulsion.

An entirely different source of soluble oil wastes is the quenches used in certain heat-treating and annealing operations. In the heat-treating departments of a nut and bolt factory three different types of operations were encountered in which soluble oil was used in the quench.

In one, the quench bath consisted of 1 part of Sunoco slushing oil to 20 parts of water. In some instances this emulsion was continuously circulated from a reservoir, through the quench tank, through a tube and shell cooler, and back to the reservoir. In others, the quench tank was filled with emulsion from the reservoir only once, and after use was drained back to it. Cold water was circulated through coils in the quench tank to cool the emulsion during the actual operating period. In neither of these cases did any emulsion reach the sewer, except as drag out on the product or at the infrequent periods when the emulsion reservoirs were cleaned out.

In another operation the quenching liquid was essentially water, and the quench tank was operated with a small but continuous overflow estimated at about 5 g.p.m. However, small amounts of soluble oil were added to the quench tank (1,300- to 1,600-gal. capacity) at frequent intervals. On the average, about 1 qt. of soluble oil per hour was used. Thus, the overflow contained about 0.08 per cent soluble oil and, of course, flowed directly to the sewer.

In the third operation, used for blackening lag screws, etc., the quench tank is first filled with 1:20 emulsion, then cold water is turned into the tank and allowed to overflow continuously at a sufficient rate to maintain the desired quenching temperature. Soluble oil is added to the tank, a quart at a time, to prevent excessive dilution of the emulsion. At the end of the run the contents of the quench tank are, however, too dilute to return to the reservoir and are flushed to the sewer.

Still other heat-treating operations used either clean water or true quenching oil baths. None of the quenching oil reached the sewer at the heat-treating department, but some was carried out to washing machines as previously described. The survey showed that the use of both water and soluble oil was highly variable in the heat-treating operations. In the particular installation studied, there were 6 furnaces having a total quench tank volume of 6,300 gal. Indications are that even after segregating as much clean water as possible the water discharge might range from 7,000 to 100,000 g.p.d and might contain up to 204 gal. of soluble oil. The average discharge was about 43,000 gal. of waste, containing 80 gal. of oil, or about 0.2 per cent. By way of comparison, the routine soluble oil wastes from cutting, threading, machining, washing machines, etc., at the same plant average only 2,100 gal. per 16-hr.

day, of which about 50 gal. or 2.4 per cent, were soluble oil.

Still another and entirely different source of soluble oil wastes is from certain cold rolling operations. When rolling certain types of steel, a thin stream of soluble oil emulsion is continuously played on the strip as it passes through the rolls. Usually the rolls are water cooled, and in practice it is impossible to prevent the spent emulsion and spent water becoming mixed so that again, the soluble oil waste to be treated is quite dilute. To date, it has been impossible to separate these wastes from other rolling mill wastes at any of the mills studied, so no data can be given on their volume or actual oil content.

Some types of rolls are lubricated with soluble oil emulsions. In these cases, the emulsion is continuously circulated from a reservoir, through the bearings, and back to the reservoir. Sufficient pressure is maintained throughout the circulating system so that cooling water cannot become mixed with the emulsion and dilute it. However, as the machines become old, some of the emulsion may escape from the bearings and reach the sewer along with the spent cooling water. Periodically the reservoirs are drained and washed out.

Small amounts of soluble oil usually are added to the water used in accumulators and hydraulic piping of presses. This is done to reduce rusting and avoid sticking of valves. Sometimes, pressures as high as 5,000 lb. per sq. in. are carried in these systems. At such pressures it is difficult to eliminate leakage entirely and some oil reaches the sewer. Frequently, it is practically impossible to intercept this leakage before it is diluted with large volumes of spent cooling water.

Analyses of Emulsions

The laboratory studies were conducted, in part, on samples of actual emulsions in use in certain plants and, in part, on synthetic emulsions prepared by mixing various soluble oils with Pittsburgh tap water. These basic emulsions were then diluted to various degrees for experimentation. Table I contains analyses of the initial emulsions. All analyses were made in accordance with the standard methods (6), except that chloroform was used as the solvent instead of ether. All "oil" determinations were made by Soxhlet extractions as these gave much

TABLE I.—Analyses[1] of Basic Soluble Oil Emulsions

Soluble Oil		Chloroform Extract[2] (% by wt.)	Residue on Evaporation (% by wt.)	Loss on Ignition of Residue (% by wt.)	pH	Phenolphthalein Alkalinity[3] (p.p.m.)	Methyl Orange Alkalinity[3] (p.p.m.)	5-day B.O.D. (p.p.m.)
Type	(% by vol.)							
Solvac[4]	25.0	21.32	21.39	20.42	9.5	—	—	—
Kut-well[5]	—[6]	1.74	1.79	1.72	8.5	0	187	—
Kut-well[7]	1.8	1.75	1.54	1.51	7.6	—	—	—
Sunoco[7, 8]	16.7	16.25	13.97	13.64	9.9	450	2,600	—
Vantrol 523[7]	12.5	10.04	9.39	9.28	7.2	0	1,660	—
Cimcool[7]	4.5[9]	0.63	1.24	1.08	8.6	540	4,300	4,230

[1] Averages of 2 or more independent determinations.
[2] Oil.
[3] As $CaCO_3$.
[4] Plant A, tapping dept.
[5] Plant B, cold nut dept.
[6] Unknown.
[7] Synthetic laboratory emulsions made with Pittsburgh tap water.
[8] Slushing oil.
[9] 4 per cent Cimcool compound and 0.5 per cent Cimcool conditioner.

higher and more constant results than did the wet extraction procedure. Table I shows that practically all of the Solvac, Kut-well, and Sunoco, and most of the Vantrol products, were chloroform soluble; but that a considerable portion of the Cimcool was not. In succeeding tables the term "oil" refers to chloroform extract regardless of whether it is true oil or an emulsifying agent. Apparently, some of the oil is volatilized during the long drying period required to determine the total residue, for Table I shows that in several instances the loss on ignition was lower than the chloroform extract. This was particularly true of the Sunoco and Vantrol emulsions. Data in Table I are the averages of two or more independent determinations.

Solvac Emulsions

Tests were made in connection with the problems of three different plants. At Plant A, "Solvac," as manufactured by the Socony Vacuum Oil Company, was the only soluble oil used. An emulsion of 200 gal. of oil with 800 gal. of water was stored in a reservoir, from which it was circulated through tapping machines. Normally, little or none of this emulsion reaches the sewer. However, the reservoir was cleaned out periodically, at which time the emulsion, diluted with 2 to 4 volumes of water, was discharged to the sewer over a 2-hr. or 3-hr. period. Inasmuch as gravity oil separators already were required at this plant to treat non-emulsified, oil-contaminated cooling water, it was felt that a treatment that would break the soluble oil emulsion and permit removal of most of the oil by flotation before it entered the main separator would suffice, even though such treatment did not produce an effluent with less than 30 p.p.m. of oil.

All of the laboratory tests were made on a Solvac emulsion containing 71,000 p.p.m. of oil. It was found that any of the following would almost completely break the emulsion and cause most of the oil to float:

Sulphuric acid in amounts of 145 lb. of 66° (Baumé) acid per 1,000 gal. of emulsion gave a residual liquor that was slightly cloudy and had a pH of about 2. Lesser amounts were ineffective.

Chlorine (from sodium hypochlorite) in amounts of 30 lb. per 1,000 gal. of emulsion, plus agitation, left a clear, brown colored liquid with little change in pH. However, subsequent agitation caused re-emulsification.

Sodium chloride in sufficient amounts to cause saturation gave a slightly cloudy liquor with a pH of about 5.9. Smaller amounts of salt were not tried.

Calcium chloride in amounts of 29 lb. anhydrous per 1,000 gal. produced a clear, slightly yellow residual liquor with a pH of about 8 and an oil content of 515 p.p.m. Filtration reduced the oil to 281 p.p.m., but did not eliminate the color. As little as 17 lb. per 1,000 gal. caused partial breakage of the emulsion.

Alum [$Al_2(SO_4)_3 \cdot 18H_2O$] in amounts of 42 lb. per 1,000 gal. of emulsion produced a clear colorless liquor with a pH of about 4, containing 424 p.p.m. oil. Filtration reduced the oil to 92 p.p.m. As little as 35 lb. of alum per 1,000 gal. caused partial breakage of emulsions. No amount up to 400 lb. per 1,000 gal. caused any flocculation or sludge formation, despite the alkalinity of the emulsion.

Although the manufacturer advised that alcohol would also break Solvac emulsions this was not tried.

As a result of these experiments the recommendation was made to install a 4,000-gal. tank, to which all spent emulsion and wash water used in cleaning the emulsion reservoir would be pumped. The emulsion breaking compound could be placed in the tank before it was filled, and the inlet arranged to cause sufficient agitation to dissolve the compound. The contents

of the tank would be allowed to stand quiescent for at least 1 hr. and preferably over night, so as to allow ample time for the oil to rise to the surface. The tank contents would then be slowly drained through a bottom opening. As long as the drainage was principally water, it would flow to the A.P.I. separator provided for the treatment of oil-contaminated cooling water. When the drainage from the tank became principally oil, it would be collected in drums and hauled to a burning pit.

Although the laboratory experiments showed that 42 lb. of alum per 1,000 gal. was slightly more effective in breaking the emulsion than was 29 lb. of anhydrous calcium chloride, use of the latter was recommended because: (1) at prevailing prices, the calcium chloride treatment would cost 58¢ per 1,000 gal. as compared with 98¢ for alum; and (2) the calcium chloride was less toxic than the alum. Anderson (7) shows the threshold toxicity to *Daphnia magna* to be 136 p.p.m. for $Al_2(SO_4)_3$ and 1,332 p.p.m. for $CaCl_2$. Thus, the dosage required to break the Solvac emulsion was only about 2.6 times the toxic limit in the case of calcium chloride, but about 19 times that limit in the case of alum.

Kut-well and Sunoco Emulsions

The soluble oil waste problem was much more serious at Plant B, a large screw and bolt concern. This plant used soluble oil in machining, washing, and heat-treating operations. Three different kinds of soluble oil were used —Sunoco "Emulsifying Oil," 270 gal. per month; Sunoco "Slushing Oil," 2,240 gal. per month; and Standard Oil Company "Kut-well 40," 650 gal. per month. (However, the Sun Oil Company advised that its two products were chemically identical.) The routine daily flow of soluble oil wastes would range from 9,000 to 102,000 g.p.d. and would normally contain from 0.2 to 3.0 per cent oil. No gravity separators were required on cooling water discharges, so this waste had to be completely treated.

No chemical was found that had any material effect on Kut-well emulsions containing 0.2 per cent oil by weight. Calcium chloride, alum, ferric chloride, chlorine, sodium chloride, alcohol, and sulphuric acid were tried. In all cases the emulsion retained its initial opaque white appearance. Alum did have some effect on emulsions containing more oil; that is, some oil separated and rose to the surface, but the liquor remained quite cloudy. The larger the initial oil content the less the quantity of alum required for this partial separation. For example, 10 lb. per 1,000 gal. was sufficient for a 1 per cent oil emulsion; 25 lb. for a 0.87 per cent emulsion; and 42 lb., for a 0.43 per cent emulsion: but 63 lb. had no effect on a 0.2 per cent emulsion. Increasing the alum use to 250 lb. per 1,000 gal. did not improve the separation. Ferric chloride was very inferior to alum; neither produced any coagulation, despite the alkalinity of the waste. Sulphuric acid (153 lb. per 1,000 gal.) did cause reasonably good clarification of a 1.74 per cent Kut-well emulsion in 5 to 6 hr., but had no visible effect on emulsions of lower oil content, despite the fact that their pH was reduced to about 1.3. None of the other chemicals proved effective on Kut-well emulsions, regardless of their initial oil content.

The difficulty of breaking Sunoco emulsions was intermediate between that of Kut-well and Solvac emulsions. It was found that 61 lb. of calcium chloride, 25 to 50 lb. of alum, 30 to 40 lb. of ferric chloride, or 153 lb. of 66° sulphuric acid per 1,000 gal. would cause a partial breakage of emulsions containing 1.63 per cent or more of oil. Free oil in an amount almost equal to the volume of soluble oil used in the initial emulsion rose to the surface and the underlying liquor changed from white to buff, but remained opaque.

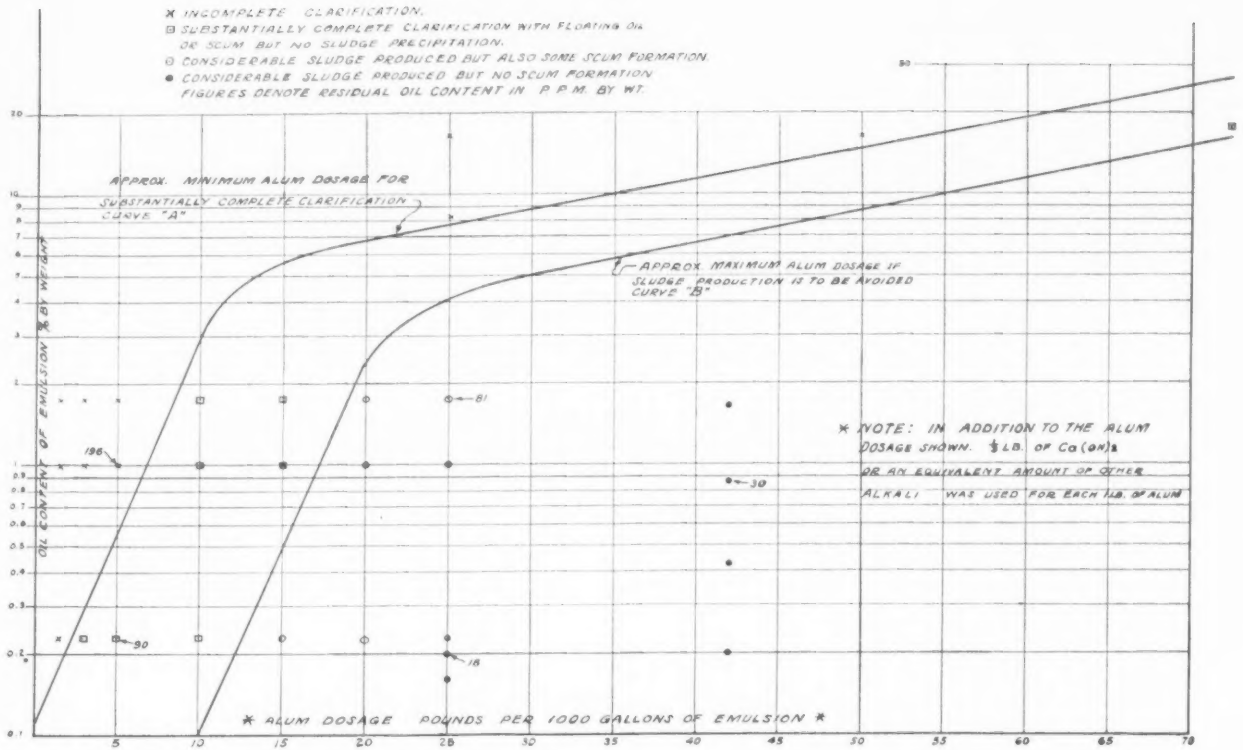
× INCOMPLETE CLARIFICATION.
⊡ SUBSTANTIALLY COMPLETE CLARIFICATION WITH FLOATING OIL OR SCUM BUT NO SLUDGE PRECIPITATION.
⊙ CONSIDERABLE SLUDGE PRODUCED BUT ALSO SOME SCUM FORMATION
● CONSIDERABLE SLUDGE PRODUCED BUT NO SCUM FORMATION
FIGURES DENOTE RESIDUAL OIL CONTENT IN P.P.M. BY WT.
APPROX. MINIMUM ALUM DOSAGE FOR SUBSTANTIALLY COMPLETE CLARIFICATION CURVE "A"
APPROX. MAXIMUM ALUM DOSAGE IF SLUDGE PRODUCTION IS TO BE AVOIDED CURVE "B"
* NOTE: IN ADDITION TO THE ALUM DOSAGE SHOWN, ½ LB. OF Ca(OH)₂ OR AN EQUIVALENT AMOUNT OF OTHER ALKALI WAS USED FOR EACH LB. OF ALUM
OIL CONTENT OF EMULSION IN % BY VOLUME
* ALUM DOSAGE POUNDS PER 1000 GALLONS OF EMULSION *

FIGURE 1.—Results of alum-alkali treatment of soluble oil emulsions.

None of these chemicals had any visible effect on Sunoco emulsions containing 0.16 per cent or less of oil.

Alum-Alkali Treatment

After conducting the foregoing experiments the conclusion was reached that even if a chemical could be found that would break all of the emulsions to such an extent that 90 to 99 per cent of the oil could be removed by flotation and skimming, the residual oil content would still be 10 to 100 times as much as the allowable 30 p.p.m., and the residual concentration of such chemicals might make the wastes toxic to aquatic life. As previously noted, alum or ferric chloride alone produces no flocculation despite the titrateable alkalinity and relatively high pH of the emulsions. However, it was found that when either hydrated lime or soda ash was added to the emulsions treated with alum or ferric chloride, a profuse floc was formed and the residual liquor appeared entirely clear. It appeared logical to believe that by the use of an alkali much smaller amounts of coagulant might be equally effective. Therefore, a series of experiments was initiated to develop the minimum alum dosage required when the theoretical amount of alkali is used in conjunction with it. Figures 1 and 2 show some of the results of those experiments. As might be expected, it was found that the minimum amount of alum (and alkali) required to produce complete clarification varied with the initial oil content of the emulsion. How-

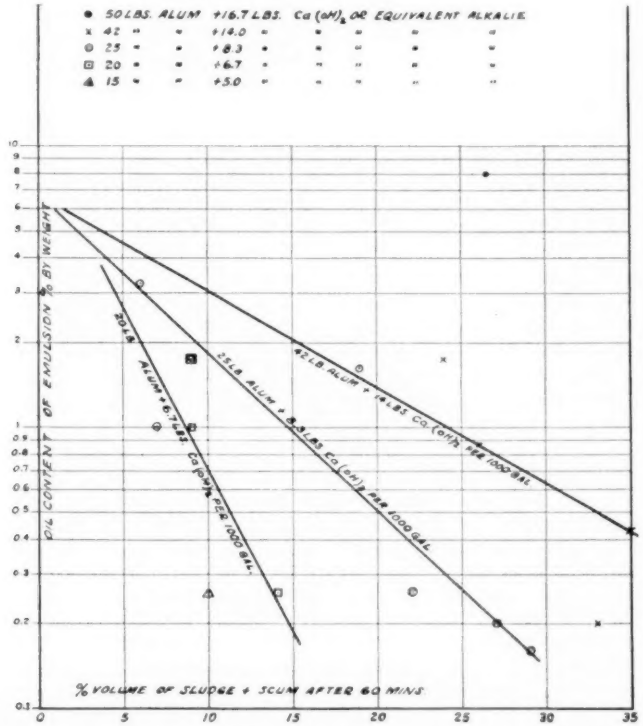
50 LBS. ALUM + 16.7 LBS. Ca(OH)2 OR EQUIVALENT ALKALIE
42 " " + 14.0 " " " " " "
25 " " + 8.3 " " " " " "
20 " " + 6.7 " " " " " "
15 " " + 5.0 " " " " " "
% CONTENT OF EMULSION % BY WEIGHT
% VOLUME OF SLUDGE + SCUM AFTER 60 MINS.
42 LB. ALUM + 14 LBS. Ca(OH)2 PER 1000 GAL.
25 LB. ALUM + 8.3 LBS. Ca(OH)2 PER 1000 GAL.
20 LB. ALUM + 6.7 LBS. Ca(OH)2 PER 1000 GAL.

FIGURE 2.—Sludge and scum formation by alum-alkali treatment of soluble oil emulsions.

ever, as indicated by Curve A (Figure 1), if the initial oil content was less than about 4 per cent, the minimum alum requirement was relatively constant and by no means directly proportional to the oil content. In contrast with this phenomenon, the alum requirements increased in practically direct proportion to the initial oil content as it increased beyond 5 per cent.

It was also found that if the alum dosage did not greatly exceed the minimum dosage the floc formed was very light and all rose to the surface. The resulting scum was small in volume (usually less than 3 to 5 per cent), but formed a soapy, sticky, mass which might be difficult to handle on a large scale. If the alum dosage was increased further, some of the floc settled to the bottom to produce a very light sludge that did not concentrate or compact very rapidly. As indicated by Curve B (Figure 1) the maximum permissible alum dosage, if sludge production is to be avoided, bears substantially the same relationship to the initial oil content of the emulsions as does the minimum dosage required for clarification. A few of the tests indicated that if excessive amounts of alum were used all the floc settled and no scum was formed. Perhaps, if more points were available, a third curve might be drawn indicating the minimum alum dosage required for scum avoidance. However, the tests indicate that, at such alum dosages, the volume of sludge produced would be so excessive as to greatly increase the cost of sludge disposal. Figure 2 shows that for a given initial oil content the volume of sludge and scum together increases enormously as the alum dosage exceeds that called for by Curve B of Figure 1. It is interesting to note that the lines for various alum dosages shown in Figure 2 appear to converge at about 4 to 6 per cent initial oil content, and that the inflection points of Curves A and B of Figure 1 occur at those same oil contents.

The final pH, determined after each test, ranged from 9.0 to 5.0. There appeared to be no correlation between the final pH and either the initial oil content, the alum dosage, the degree of clarification, or the volume of sludge and scum produced. Unlike the previously described tests, the alum-alkali treatment appears equally effective on Sunoco and Kut-well oil emulsions. The only difference observed was that the final pH of the Sunoco slushing oil emulsions ranged from 8 to 9, whereas that of the Kut-well emulsions ranged from 5 to 7.

In order to minimize the laboratory work only a few residual oil determinations were made, as indicated in Figure 1. More determinations are required to warrant definite conclusions. However, it appears that, although the use of alum dosages between Curves A and B in Figure 1 may produce a clear effluent with an oil content of perhaps 100 p.p.m., it will be necessary to use considerably more alum than indicated by Curve B if the state requirement of only 30 p.p.m. is to be met. The use of such large quantities of alum will not only increase the cost of chemicals, but also the volume, and hence the cost, of sludge and scum disposal.

Theoretically, for minimum chemical cost, it would be desirable to regulate the feed of alum and alkali in proportion to the initial oil content, as well as the volume of the emulsion being treated. To do this it not only would be necessary to have a technically trained operator in constant attendance, but also to have available a rapid test procedure for approximating the initial oil content. A test procedure consisting of collecting a sample in a graduate, acidifying, shaking, and reading the volume of floating oil after 5 or 10 min. might suffice for Solvac, Sunoco, or possibly some other emulsions, but no rapid test procedure applicable to Kut-well emulsions is known to the writer. Fortunately, it appears

from Figure 1 that as long as the initial oil content does not exceed 3 per cent chemicals can be fed in proportion to the flow of emulsion being treated, irrespective of its oil content. Equipment is readily obtainable for automatically maintaining such proportions. Thus technical control can be reduced to the barest minimum without undue sacrifice of efficiency. Even if satisfactory test procedures were available, the saving in chemicals possible by varying their application in accordance with the initial oil content would not warrant the added cost of technical supervision.

At Plant B, where the wastes had an oil content of 0.2 to 3.0 per cent, it would appear that the application of 25 lb. of alum and 5.5 lb. of dolomite quicklime per 1,000 gal. might be expected to give close to maximum oil removal. Assuming that the wastes averaged 45,000 g.p.d. with 0.3 per cent oil, sludge and scum production would average 24 per cent by volume after 60-min., or 20 per cent after 2-hr. sedimentation; that is, about 960 cu. yd. per month. With alum costing $2.25 per 100 lb. and dolomite lime costing $16.88 per ton, the chemical cost would be about $557 per month. At $0.35 per ton, sludge disposal costs might be an additional $290.

Other Coagulation Treatments

Presumably, any combination of chemicals that will produce coagulation will result in apparently complete clarification so far as the naked eye can discern. Fifteen tests were first run with ferric chloride and lime as the coagulants. Trials were then made with calcium sulphate, formed "in situ" by the addition of lime to acidified samples of 9 different emulsions. Good clarification was obtained on both Sunoco and Kut-well emulsions of wide variation in oil content (Table II). Although the tests of these combinations were not as extensive as those on the alum-alkali treatment, they did not seem to indicate much possibility of reducing either chemical or sludge disposal costs. Because any plant designed for alum-alkali treatment could utilize either of these other chemical combinations with little or no change in design, further laboratory study was not considered worthwhile.

Joint Treatment with Pickling Wastes

In addition to providing treatment for soluble oil emulsions at Plant B, it was also necessary to provide treatment for pickling wastes. The lime treatment of pickling wastes produces a flocculant sludge, which should be as capable of absorbing the oil as any of the sludges previously considered. Therefore, it was decided to experiment on the joint treatment of the two wastes together.

A synthetic pickle waste containing 0.0302 lb. of iron and 0.022 lb. of free

TABLE II.—Representative Results of Treatment of Soluble Oil Emulsions by Ferric Chloride-Lime and Acid-Lime

Type of Treatment	Type of Oil	Initial Oil Content (% by wt.)	Reagent Used (lb. per 1,000 gal.)			Sludge and Scum Produced[3] (% by vol.)	Final pH	Residual Oil (p.p.m.)
			$FeCl_3$[1]	H_2SO_4[2]	$Ca(OH)_2$			
Ferric chloride-Lime	Kut-well	0.87	40	—	27.5	39	6.3	22
	Sunoco	8.13	40	—	19.0	31	3.6	12
Acid-Lime	Sunoco	16.25	—	153	116	38	11.8	87
	Sunoco	1.63	—	153	116	56	3.1	39

[1] Anhydrous. [2] 66° Baumé. [3] 60-min. settling.

100 per cent H_2SO_4 per gal. was made up in the laboratory by adding ferrous sulfate crystals and concentrated sulphuric acid to tap water. This solution was substantially equivalent to the routine flow of rinse water and bundle drippage from pickling operations. The synthetic pickle waste was mixed with various oil emulsions in different proportions and then treated with dolomite lime in a milk of lime suspension.

Dolomite lime was used because it was hoped that it would produce less sludge than high-calcium lime. The actual volume of sludge produced with either chemical depends on many factors, including the amount of chemical used, its degree of fineness, whether it is applied dry or wet, the duration and thoroughness of mixing, the amount of aeration, and the final pH. A suitable mechanical stirring device was not available; all samples were violently shaken by hand for about 2 min. It seems probable that had a longer and more uniform mixing been possible more consistent results than those shown in Table III might have been obtained.

Stoichiometrically, 44.5 lb. of dolomite lime per 1,000 gal. of pickle liquor should neutralize the free acid, precipitate the iron, and produce a final pH of about 8 or slightly higher. It will be noted that, even in the samples of 100 per cent pickling waste, the final pH was never that high and that there was no correlation between that pH and the amount of lime added. It seems apparent that, due to inadequate mixing, lime utilization was not uniform or complete in the experiments. It is believed that this same non-uniform mixing may account for the wide, and apparently inconsistent, variations in sludge volumes observed.

Despite these obvious objections and inconsistencies, the results did show that the joint treatment of the two wastes is entirely feasible and requires no more lime than does the treatment of the pickling waste alone. The meager oil determinations indicate that the joint treatment is at least as effective in removing oil as is the alum-alkali treatment previously discussed. The joint treatment appears to be equally effective on Sunoco and Kut-well emulsions; however, certain minor differences were noted. For example, the simple mixing of pickling waste with the Sunoco emulsions caused partial but not complete breaking; it had no such effect on Kut-well emulsions. Another difference noted was a greater tendency to scum formation with the Kut-well emulsions than with the Sunoco emulsions, despite the fact that, in general, the mixed Sunoco wastes contained more oil than the Kut-well mixtures.

Sludge volumes varied so widely that it is hazardous to draw conclusions. If averages are valid, it appears that the joint treatment would result in about 35 per cent more sludge than would be produced from treating the pickling waste alone. This might be logically explained on the theory that the absorbed oil decreased the specific gravity of the individual floc and retarded the rates of sludge settling and compaction. However, as shown in Table III, there was no correlation between the sludge volume and the oil content of the mixed wastes; possibly the non-uniform and inadequate mixing accounts for the variation of sludge volume in the mixed wastes as well as in the straight pickling waste. The only safe conclusion is that the joint treatment may increase sludge volumes some, but probably not more than 35 per cent.

From studies not included here it is estimated that the dolomite lime treatment of pickling wastes alone at Plant B would produce about 685 cu. yd. (631 tons) of sludge. A 35 per cent increase would be only 240 cu. yd. due to oil emulsions, instead of the 960 cu. yd. per month to be expected from their separate treatment by the alum-alkali process. Therefore, the joint

TABLE III.—Lime Treatment of Pickling Wastes

Initial Oil Content			Volumetric % Treated		Lime Used[1] (lb. per 1,000 gal. pickle waste)	Sludge and Scum Produced[2] (% by vol.)		Final pH	Residual Oil (p.p.m.)	
Type in Emulsion	Emulsion (% by wt.)	Mixed Wastes (% by wt.)	Emulsion	Pickle Wastes		Of Mixed Waste	Of Pickle Waste		Of Mixed Waste	Of Emulsion
(*a*) Pickling Wastes Alone										
None	—	—	0	100	37.6	17	17	6.1	—	—
			0	100	44.0	20	20	5.5		
			0	100	50.5	27	27	5.4		
			0	100	63.3	34	34	6.0		
			0	100	41.2	11	11	5.9		
Average	—	—	—	—	47.3	—	22	5.8	—	—
(*b*) Pickling Wastes Mixed with Soluble Oil Emulsions										
Kut-well	0.017	0.012	70	30	39.0	9	30	5.9	—	—
Kut-well	0.174	0.122	70	30	39.0	5	17	5.6	47	67
Sunoco	0.33	0.17	50	50	55.2	13	26	6.7	6	9
Kut-well	0.35	0.245	70	30	39.0	9	30	5.9	—	—
Sunoco	0.33	0.25	75	25	55.2	14	56	7.2	27	36
Sunoco	0.33	0.30	90	10	69.0	6	60	7.2	45	50
Kut-well	0.87	0.43	50	50	43.4	8	16	5.7	—	—
Kut-well	0.87	0.61	70	30	39.0	5[3]	17	5.9	—	—
Sunoco	1.63	0.82	50	50	55.2	7	14	7.0	42	84
Kut-well	1.74	0.87	50	50	43.4	8[3]	16	6.1	—	—
Sunoco	1.63	1.22	75	25	55.2	7	28	7.0	—	—
Sunoco	3.25	1.63	50	50	55.2	14	28	6.8	—	—
Sunoco	3.25	2.44	75	25	55.2	7	28	7.0	—	—
Sunoco	16.25	8.13	50	50	55.2	24	48	—	—	—
Average	—	1.232	64	36	49.9	—	30	6.5	34	49

[1] Hydrated dolomite lime.
[2] 60-min. settling.
[3] Includes 1 per cent scum; very little scum formed in other tests.

treatment appeared preferable, not only because of lower chemical cost, but also because of reduced costs of sludge disposal.

Preliminary Design of Treatment Recommended for Plant B

As previously stated, the volume of soluble oil wastes from Plant B might range from 9,000 to 102,000 g.p.d. This is so great that continuous flow treatment seemed necessary. The plant also produced about 69,000 gal. of pickling wastes per 16-hr. day. Although most of this was rinse water, it did contain sufficient acid and iron to provide at least the minimum required for treatment of the oil wastes. Estimates showed that it would be cheaper to treat all pickling wastes in a continuous flow plant, than to separate and store only the spent pickle liquor for treatment in a smaller plant. Therefore, it was decided to recommend a joint treatment plant for all pickling and soluble oil wastes. The plant was designed for a maximum flow of 250 g.p.m., although the average flow is expected to be about 130 g.p.m.

Figure 3 is a flow diagram of the recommended treatment facilities. They would be constructed in an existing

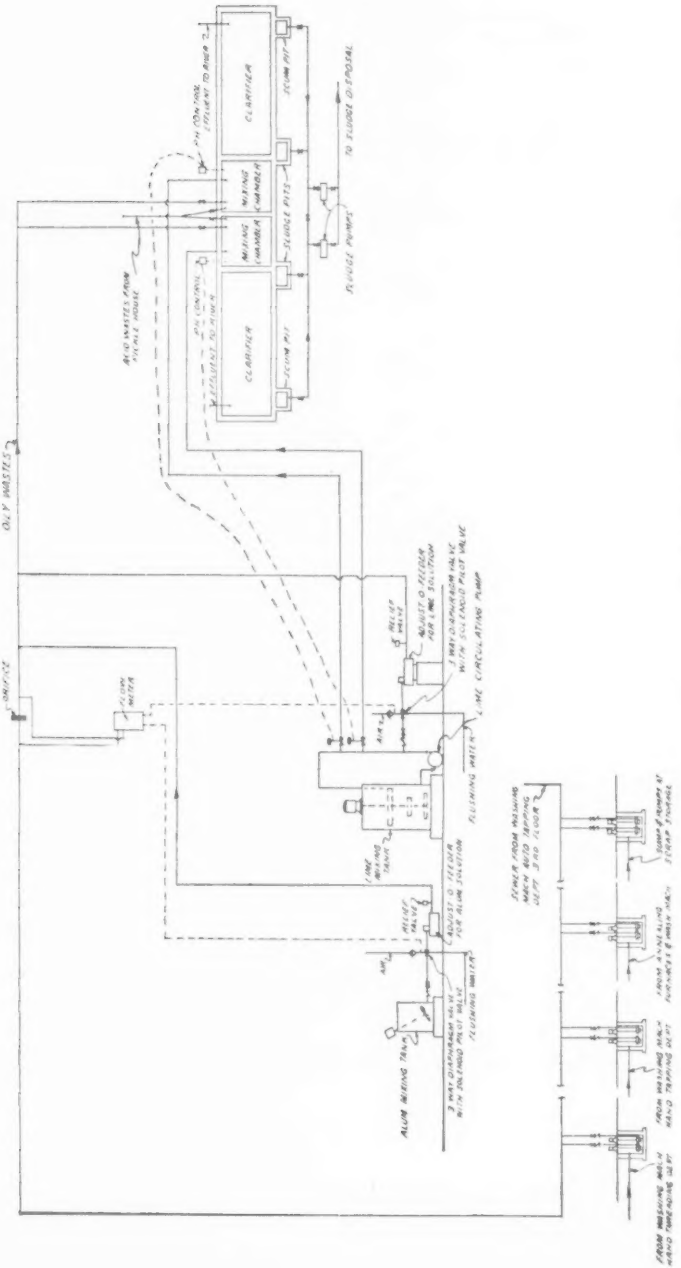

FIGURE 3.—Flow diagram for joint treatment of soluble oil wastes and pickling wastes at Plant B.

basement below the pickling department so pickling wastes would flow to it by gravity. Soluble oil wastes would be pumped to the plant by a number of strategically located sump pumps. As indicated in Figure 3, the plant would consist of two mixing basins and two clarifiers, together with the necessary chemical feeds, sludge pumps, and other appurtenances.

Normally, the two mixing basins will operate in parallel and flow of both wastes will be equally divided between them. When so operated, the basins would provide a mixing period of 35 min. at maximum design flow. Each basin will be provided with either a turbine or propeller-type equipment designed to circulate 4,000 g.p.m.; that is, to turn over the basin contents almost once a minute. Mixing basins and agitators would be of acidproof construction. Most of the time lime would be the only chemical added. Milk of lime would be pumped to each basin through valves automatically controlled to maintain a pH of 8.5 to 9.0 in the basins.

From the mixing basins the coagulated wastes would flow to the clarifiers. At maximum design flow the clarifiers will have a theoretical detention period of 2 hr., a settling rate of 620 gal. per sq. ft. per day, and an overflow rate of 6.3 g.p.m. per foot of effluent weir. The clarifiers will be equipped with mechanical scum and sludge collectors discharging to sumps. Sludge pumps will deliver the collected material to either a sludge storage and concentration tank, or directly to a barge for conveyance to the point of ultimate disposal by lagooning.

Because all the pickling wastes are produced in 16 hr., whereas soluble oil wastes are produced over the entire 24 hr., it is necessary to provide facilities for treating the latter wastes by the alum-alkali process during the periods when no pickling waste is available. At such times the pH-controlled feeding of lime would be discontinued and a flow-controlled system would be put into operation. Oil wastes would be measured through an orifice meter and both alum and lime solutions would be injected before they entered the mixing basins. It is not expected that the treatment will remove all of the iron, but it is hoped that the effluent will not contain more than 100 p.p.m. of iron or 30 p.p.m. of oil.

Vantrol and Cimcool Emulsions

The third plant, Plant C, for which soluble oil treatment facilities have been recommended, is a large engine manufactory. This concern uses two soluble oils (Vantrol 629A and 523) and the pink Cimcool compound previously described; the latter is gradually displacing the Vantrols in most departments. In addition, four different true cutting oils are used. The problem at this plant was disposal of drainage from piles of cuttings stored in the open. Such drainage was a mixture of the various emulsions and true cutting oils with variable amounts of dilution due to storm runoff. Laboratory studies were first run on various dilutions of the three separate emulsions, and then on mixture of those with one or more of the true cutting oils.

The Vantrol 629A emulsion most commonly used in the shops contains 2.5 per cent of that compound by volume. However, the tests were run on emulsions containing 10, 2, and 0.84 per cent, respectively. Attempts to break the emulsions were made with calcium chloride, alum, and epsom salts. Both alum and epsom salts caused some precipitation in the strongest emulsion, but poor clarification. Calcium chloride gave the best results, causing a volume of free oil, equal to about half the volume of soluble oil originally used, to rise to the surface. However, the residual liquor remained cloudy. Judging from appearance only, 30 lb. of anhydrous salt per 1,000 gal. was as effective as 300 lb. A sample of the strongest emulsion, after

treatment with 180 lb. of $CaCl_2$, contained 870 p.p.m. of chloroform extract. The action was slower on the more dilute emulsions. The alum-alkali treatment previously described was very effective; 21 lb. of alum and 7 lb. of lime per 1,000 gal. gave a crystal clear liquor, but produced 15 to 30 per cent sludge.

The Vantrol 523 emulsion most commonly used in the shop contained 3.3 per cent of that compound by volume. However, the tests were made on emulsions containing 12.5 and 1.25 per cent, respectively. Either alum or calcium chloride would break these emulsions almost as completely as they broke the Solvae emulsions described earlier. About 30 lb. of calcium chloride per 1,000 gal., or 21 to 42 lb. of alum, proved adequate. A sample of the strongest emulsion, after treatment with 60 lb. of $CaCl_2$, contained only 250 p.p.m. of chloroform extract. Alum produced no coagulation, either when used alone or in combination with lime. Thus, the alum-alkali treatment was no more effective than the single chemicals on emulsions of this oil. Other chemical combinations that might have produced coagulation were not tried.

The Cimcool emulsion most commonly used in the shop contained 4.0 per cent Cimcool compound and 0.5 per cent Cimcool conditioner by volume. Tests were made on such an emulsion, and on 50 per cent and 10 per cent dilutions of it. No single substance was found that would break any of the mixes, although calcium chloride, alum, epsom salts, sodium chloride, ferric chloride, ferrous sulphate, alcohol, chlorine, lime, and sulphuric acid were tried. Lime came the closest, as it produced some coagulation and precipitation. However, the residual liquor remained a very cloudy opaque pink. It was found that the alum-alkali treatment, using as little as 21 lb. of alum and 7 lb. of lime per 1,000 gal., gave excellent coagulation and left a perfectly clear liquor having a red to pink color, depending on the strength of the initial emulsion. An increase in chemical dosage reduced the intensity of this color slightly, but even a 500 per cent increase did not eliminate it. Table IV shows some of the results obtained with this treatment. It was found that ferric chloride and lime also would produce a clear supernatant, but resulted in more sludge and no better, if as good, color removal. The manufacturer of this compound advises that treatment with 40 lb. of magnesium sulphate and 20 lb. of Naccconol N. R., or similar wetting agent, will break the emulsion and cause most of the oil to float. This treatment was not tried, however.

When the various true cutting oils were mixed with emulsions of Vantrol 629A, most of them went into emulsion. However, either calcium chloride or alum-alkali would break these emulsions in 3 to 17 hr. None of the cutting

TABLE IV.—Alum-Alkali Treatment of Cimcool Emulsions

Original Emulsion (% by vol.)			Chemicals Used (lb. per 1,000 gal.)		Sludge Produced (% by vol.)		Color of Clear Supernatant	Oil[1] (p.p.m.)		5-day B.O.D. (p.p.m.)	
Cimcool Compound	Cimcool Conditioner	Pittsburgh Tap Water	Alum	Lime	30 Min.	120 Min.		Initial	Final	Initial	Final
4.0	0.5	95.5	21	7	9	16	Red	6,300	27	4,230	369
2.0	0.25	97.75	21	7	15	—	Pink	—	—	1,870	194
0.4	0.05	99.55	21	7	8	—	Light Pink	—	—	388	44

[1] Chloroform Soxhlet extract.

oils formed emulsions with the Cimcool mixes, but unless they were skimmed off the quantity of alum and alkali required to clarify the Cimcool mixes was approximately doubled.

As a result of these experiments it was recommended that all cutting drainage at Plant C be pumped to a tank arranged for air agitation and provided with multiple outlets at 1-ft. differences in elevation. When the tank fills, alum and lime in amounts of 42 and 14 lb. per 1,000 gal., respectively, will be added and the contents agitated for 30 min. After standing overnight, the clear liquor would be drawn off to the sewer and the remaining sludge and scum hauled to a dump. It is expected that this treatment will reduce the volume of wastes to be hauled by 50 to 75 per cent.

Conclusions

Any conclusions drawn entirely from laboratory studies must be considered tentative until confirmed by plant scale operations. However, it is felt that submission of the following is warranted:

1. There are wide differences in the components of the various soluble oils on the market and also in the relative proportions of those components. It would not be surprising if these differences necessitated corresponding variations in treatment of wastes resulting from these oils. Eldridge and Purdy (1) apparently tested five of the many different oils on the market and found that emulsions of all five could be broken in much the same manner. In the study described herein six were tested and almost the exact reverse was found to be the case.

2. Actual field observations show that there is a wide variation in the oil content of soluble oil wastes. Eldridge and Purdy (1) indicate a range of 1 to 10 per cent and considered 5 per cent typical. In this study a range of from less than 0.1 per cent to 20 per cent was encountered.

3. The laboratory studies clearly showed that, for a given soluble oil, the higher the oil content of the emulsion, the easier it was to break the emulsion. Several manufacturers of soluble oils advise that this is to be expected. However, meager data on different dilutions reported by Eldridge and Purdy (1) do not bear out this conclusion.

4. Apparently there are a number of different electrolytes that will partially or completely break emulsions of several different soluble oils, but not all. Both the test results and those of Eldridge and Purdy (1) showed calcium chloride to be one of the most effective. However, the quantity of electrolyte required is frequently so great that it might make the effluent toxic to aquatic life unless considerable dilution is available.

5. Apparently none of the electrolytes tried by Eldridge and Purdy (1) or in the present tests are capable of completely breaking the emulsions and producing effluent suitable for discharge directly to the receiving stream. In general, the effluent will have an oil content of 200 p.p.m. or more.

6. Despite the fact that most soluble oils are highly alkaline, the addition of coagulants such as alum, ferric chloride, and either ferrous or ferric sulphate to the emulsions usually does not produce any coagulation or flocculation. However, if additional alkali is also added, the emulsion is broken in most cases, much of the oil is coagulated, and an effluent suitable for discharge is produced. This is not only true of the usual flocs of aluminum and iron hydroxides, but also of calcium sulphate formed "in situ" by the reaction of lime and sulphuric acid. Other precipitates may have a similar effect.

7. When emulsions high in oil are so coagulated some free oil, or the flocculated material, may float and have to be removed as scum instead of sludge. The tests showed that increasing the

amount of coagulant reduced this tendency. Eldridge and Purdy (1) found that the addition of bentonite along with the coagulants had a similar effect.

8. Treatment may be either by a two-stage process consisting of first breaking the emulsion and floating off the oil, followed by coagulation as suggested by Eldridge and Purdy, or by coagulation alone. The choice depends on the susceptibility of the emulsion to breakage without coagulation, the cost and availability of coagulating chemicals, the oil content of the waste to be treated, and the value of the free oil that might be recovered from the first stage. If the oil content of the emulsion is less than 4 per cent, or an abundance of pickle liquor requiring treatment is available, it is not believed that the two-stage process is warranted. Obviously, it is useless if the emulsion cannot be broken in the first stage without adding so much electrolyte as to offset the saving in coagulant required or to produce a toxic effluent.

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THE POSSIBILITIES OF DISPOSAL OF RADIOACTIVE WASTES BY BIOLOGICAL TREATMENT METHODS *

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The purpose of this paper is to discuss the possibilities of the application of biological treatment procedures to waste disposal problems of nuclear operations.

At Oak Ridge and elsewhere, it has been observed that as waste waters containing minute quantities of nuclear fission wastes are discharged into ponds and streams the mechanical, chemical, and biological processes of natural purification reduce the intensity of the radioactivity of the water. This reduction is over and above that expected from the decay which all radioactive substances undergo. Examination of the bottom muds and biological flora and fauna in the stream shows that these components have adsorbed some of the radioactive constituents and have served as concentrators. It has been observed also that algae and other aquatic plants may grow prolifically in water that has considerable radioactivity. The use of a controlled microflora and fauna for the adsorption and concentration of radioactive waste products, particularly those with long half-lives that could create serious hazards, deserves careful study.

Biological Treatment Methods

The biological processes that have been developed for treatment of domestic sewage and of organic wastes, which might be applied here, include the trickling filter, or bio-filter, and the activated sludge process. Each of these processes has characteristics that would permit adsorption and removal of radioactive constituents during the normal bio-chemical reactions of the process; each has advantages and disadvantages when applied to sewage and industrial wastes. Although the mechanics, structure, and operation of the two processes are quite different, the fundamental biological mechanisms of both are very similar. It has been demonstrated that the predominant bacteria responsible for the bio-chemical changes in both processes are the zoogleal bacteria (1) (2) (3) (4).

The activated sludge process seems to possess certain advantages for application to radioactive waste water treatment. These apparent advantages include:

1. Smaller size and cost of installation needed.
2. Greater control of and ease in handling, removal, and disposal of zoogleal sludges that have become radioactive.
3. Greater flexibility for manipulation and control of the process.
4. Better possibilities of minimizing human exposure.
5. Greater adaptability for experimentation on a laboratory and pilot plant scale.

Fundamental Principles

There are, to be sure, many problems that must be resolved before any biological process can be successfully applied to this new field of waste treatment. Before considering these problems in detail, a brief review of the fundamental principles involved in the operation of the activated sludge proc-

* Presented at Seminar on the Disposal of Radioactive Wastes, sponsored by the U. S. Atomic Energy Commission, Washington, D. C., January 24–25, 1949.

ess seems in order. This process may be more generally defined as an oxidative assimilation in which waste organic products or sewage are utilized aerobically by zoogleal bacteria, with the assimilation of part of the food into zoogleal flocs tenaciously held together by a gelatinous matrix. These colonies of zoogleal bacteria with their tenacious gelatinous matrices seem to be one of the most important characteristics of a good activated sludge. The tremendous surface areas of massive colonies of the zoogleal bacteria enable them to enmesh and adsorb particulate and colloidal matter and materials in true solution in their normal metabolism, thereby sweeping the substrate clean and resulting in a clear, sparkling supernatant. The foregoing result occurs only when a good sludge has had sufficient contact with the sewage or waste substrate under aerobic conditions in the proper temperature and pH range. Although normal activated sludge is a mixed culture of zoogleal and other bacteria, which contains also flagellates, protozoa, amoebae, and fungi, it has been demonstrated that the purification of synthetic and sterile sewage can be accomplished with pure cultures of zoogleal bacteria alone (2).

Studies on the metabolism of activated sludge fed with substrates containing various organic compounds, including sugars, aldehydes, organic acids, amino acids, etc. (5) (6) (7), have shown that a wide variety of these compounds can be utilized as food. The proportions of the compounds utilized to build protoplasm and oxidized to CO_2 and H_2O depend on the compounds. In general, a larger proportion of the carbohydrates is synthesized to protoplasm, whereas greater proportions of organic and amino acids are oxidized. The end products of the metabolism of zooglea, besides protoplasm, appear to be CO_2 and H_2O for carbonaceous materials and NH_3, CO_2 and H_2O for compounds containing both nitrogen and carbon. Consequently, no offensive odors are obtained in this process when it is well operated. In the normal activated sludge process treating sewage, the excess ammonia nitrogen may be nitrified to nitrite and nitrate by the nitromonas and nitrobacter if the aeration period and sludge concentration are suitable for this purpose.

Other factors (besides nutrient substrates, mineral substrate content, pH, and temperature) that are important to the success of the activated sludge process include the quantity of active material in the aeration tanks, the aeration period, the design of the settling tanks, the percentage of sludge return, and last, but not least, the settling characteristics of the sludge itself, as indicated by the sludge index. All of the foregoing factors and relationships must be taken into consideration in the development of a biological zoogleal floc procedure that may be used successfully to remove radioactive materials from nuclear fission wastes.

Objectives of Biological Treatment of Radioactive Wastes

It should be remembered that although the common purpose of the activated sludge process is to remove organic material from suspension and solution, the purpose for which it will be applied to waste waters from nuclear fission operations is quite different. Here the purpose will be to adsorb, hold, and remove long-life radioactive inorganic isotopes during the normal development and propagation of the cultured floc.

There are three principal and important differences between the ordinary activated sludge treatment of sewage and the application of a zoogleal floc process to radioactive waste treatment. First, the radioactive contaminants probably will be present in extremely low concentrations compared to the concentrations of constituents ordinarily found in sewage or the common organic industrial wastes. For exam-

ple, the concentration of organic food that is to be removed from a sewage may be 200 to 300 p.p.m., which is 2 or 3×10^{-1} gram per liter. In the nuclear fission waste it may be necessary or desirable to remove a radioactive isotope that is present to the extent of only 1 microgram—that is, 10^{-6} gram per liter, or 1 p.p.b. The second important difference is that, although in the ordinary activated sludge process organic material that is largely utilized and oxidized is removed, here inorganic material that is probably not utilizable or of any benefit to the biological floc is to be removed from the substrate. Finally, the material to be removed here is radioactive and there is very little information about the tolerance of zoogleal flocs to radioactive isotopes and related ions and compounds that may be wasted.

Results of Experiments with Activated Sludge

Because of the policy of the Atomic Energy Commission to reduce hazards from radioactive or toxic wastes to an absolute minimum, a cooperative study (between the A.E.C., the University of California, and the U.S.P.H.S. Environmental Health Center) on waste treatment is underway at Los Alamos, N. Mex. Although the Los Alamos activated sludge experiments have only been underway for a short time, and it is not the purpose of this paper to describe them, it will be necessary to consider their implications in order to discuss intelligently the problems and possibilities of biological treatment.

These experiments have been made on sewage to which plutonium is added. Plutonium is a long half-life alpha emitter. On the basis of certain assumptions, health physicists have estimated tolerance values for plutonium in drinking water to be between 0.02 and 0.08 microgram per liter (8). A residual plutonium content of 0.001 microgram per liter in a treated effluent should be a satisfactory objective. One microgram of plutonium produces about 70,000 alpha counts per minute. In the experiments to date, a standard solution of a plutonium salt was added to give a concentration of 1.4 micrograms per liter of sewage. The experiments were conducted on a 24-hr. aeration and feeding cycle; that is, each day the sludge was settled and after the old supernatant was siphoned off, fresh sewage substrate containing the plutonium "spike" was added. The pH was within the normal range and the experiments were conducted at normal laboratory temperatures. Although difficulties were encountered in the separation and determination of plutonium in the sludge and in the supernatants after aeration, these have been overcome and some very interesting and significant results have been obtained.

It may be stated that an average reduction from 100,000 counts per min. per liter to about 3,900 counts per min. per liter in the supernatant can be expected after 23 hr. of aeration and 1 hr. of settling. This represents an average reduction of about 96 per cent in alpha count in the treated sewage. Because the counts on the supernatant effluent on some days were 6,000 per min. per liter, it has seemed that further treatment might be desirable. This additional treatment could be accomplished in a two-stage counter current flow zoogleal floc system.

New Problems and Difficulties

This study suggests that a zoogleal floc system might be successfully applied to some radioactive wastes, but it has also uncovered numerous questions and problems that must be solved before a successful plant can be designed or built. Additional laboratory experiments are underway on the effectiveness of various aeration periods, on the effect of pH and temperature changes, and on the over-all removals that may be expected in two stages of treatment. During this process the

plutonium accumulates in the zoogleal sludge floes. The upper limit of plutonium concentration that could be carried in the sludge in such a system has still to be determined.

At present, it is known that the sludge performed effectively in one series of bottle experiments through cumulative addition of 5,719,000 counts per min. to the sludge. Roughly, 150,000 counts remained in the total supernatant (55 liters) that was removed, and it may be assumed that the settled sludge liquor contained the remainder at the completion of the experiment. On this basis, it may be estimated that of 82 micrograms of plutonium that were added with the sewage, about 80 micrograms were accumulated on approximately 16 grams of zoogleal sludge (on the dry basis). If the sludge in these experiments had been settled, conditioned, and filtered, a sludge cake weighing about 80 grams and containing about 80 micrograms of plutonium might have been obtained. These experiments have demonstrated the removal of plutonium from water at a concentration of about 1.4 micrograms per liter and its possible concentration in wet sludge cake with a plutonium content of 1 microgram per gram. In other words, a 700-fold concentration of the plutonium thus would be obtained during its transference from the liquid substrate to sludge cake. It is apparent from the standpoint of economy and the problem of sludge disposal, that it would be desirable to concentrate the plutonium in the sludge to the maximum limit that would permit efficient and safe operation. It is impossible to estimate what that limit may be until additional data are obtained.

To consider the feasibility of a zoogleal floc plutonium removal plant, assume that 1 microgram of plutonium per gram of sludge cake is the upper limit of concentration possible in a plant of this kind. Suppose, also, that such a plant was designed to treat 10,000 g.p.d. of waste water containing 1 microgram of plutonium per liter. This would mean a daily contribution of 37,850 micrograms of plutonium to be removed by the zoogleal floc treatment. Suppose that that plant provided a counter current, 2-stage system that removed 99 per cent of the plutonium. This would mean that 37,470 micrograms of plutonium would be removed, and on the basis of the previously assumed limit, 37,470 grams or 82.6 lb. of wet sludge cake would be produced for disposal each day. This plant to treat 10,000 g.p.d. of waste should produce an effluent that would meet a tolerance of 0.001 microgram of plutonium per liter and at the same time require the disposal of only about 2,500 lb. of sludge cake per month.

If domestic sewage was available for development of sludge, the cost of this treatment would be somewhat higher than the cost of treating similar quantities of domestic sewage. Domestic sewage treatment by the activated sludge process may be estimated to cost about $50 per m.g., including fixed charges and operation, and about $30 per m.g. for operation alone. If the zoogleal floc sludge must be developed with foods other than sewage, the cost may be as much as 10 times that of domestic sewage treatment. However, it is certain that the cost would be low compared to some present costs of handling and treating radioactive wastes.

Nutritional Requirements and Tolerances of Zoogleal Floc Sludges

Although the application of a biological floc process has great promise for the treatment of radioactive wastes, there are innumerable problems and difficulties that must be solved or overcome. Inasmuch as some wastes that require treatment may be produced in areas in which domestic sewage is not available, it may appear at first thought that a biological process is not applicable. Such a situation is a challenge to the sanitary engineering pro-

fession and it is probable that a satisfactory zoogleal floc process can be developed in the absence of sufficient domestic sewage. As stated earlier, a variety of foods serve as satisfactory nutrients for the zoogleal floc sludges. It seems highly desirable to determine the most economical and satisfactory sources of minerals, carbohydrates, and proteins required to supplement or replace sewage in the development of satisfactory zoogleal sludges for application to the treatment of these wastes. A study of the common cheap foods as sources of carbohydrate and protein for the nutritional requirements of zoogleal floc sludges is underway at the Environmental Health Center at Cincinnati. These experiments are planned to determine what cheap foods can be easily assimilated, at the same time developing a good mixed zoogleal floc of proper ash content and density for good settling properties and with comparative freedom from dispersed particles affecting the filterability of the sludge.

Such a project may appear foolhardy to those who have experienced bulking and other operational difficulties with activated sludge, as the result of periodic discharge of food processing wastes. However, if a satisfactory food and mineral nutrient can be found for developing the zoogleal floc sludge of the proper characteristics, the advantage of positive control will be obtained and the sludge can be produced at any time in the quantities needed without dependence upon fluctuating sewage flows. Although, as previously mentioned, the use of nutrients other than sewage would increase operational costs considerably, it would enable the treatment of the waste waters without dilution in sewage and would reduce the size and cost of the plant needed for treatment of wastes from nuclear operations.

Additional problems that must be studied involve the effects of other elements and radicals that are present in some wastes. Typical examples of such materials include copper and other metal ions, the fluoride ion, and the citrate radical. Although normal activated sludge does not utilize citrate, a zoogleal floc sludge can be easily adapted to the utilization and removal of citrate. This has been established in earlier studies at Cincinnati. Recently, a study was completed of the effect of fluoride on the normal biochemical oxidation of sewage dilutions (9). This study showed that fluoride in concentrations up to 125 p.p.m. had little effect on bio-chemical oxidation rates and that consequently, the B.O.D. determination can be used in studies on wastes containing this ion. However, a special study to determine possible effects of fluoride on zoogleal floc cultures is planned.

The tolerances of zoogleal floc sludges to various metal ions and their isotopes must be established. Because some wastes contain a variety of these ions and it has been difficult to obtain their concentrations, this may require considerable study. If it is determined that some of these ions (such as copper in the concentrations found) interfere with the metabolism of the zoogleal flocs, it may be necessary to remove them by chemical pretreatment. Work on this phase of the problem is also underway at Los Alamos.

Suggested Flow Sheet

On the basis of present knowledge, a diagrammatic flow sheet of a zoogleal floc plant for treatment of waste from nuclear fission operations is shown in Figure 1. In this scheme the waste water containing long half-life alpha emitters would receive the necessary preliminary physical and chemical treatment and would flow into the dosing tank 1, where it would be mixed with sewage, other necessary food and mineral constituents, and return zoogeal sludge. This mixed liquor would then flow through the first-stage aeration tank 2 having the necessary aera-

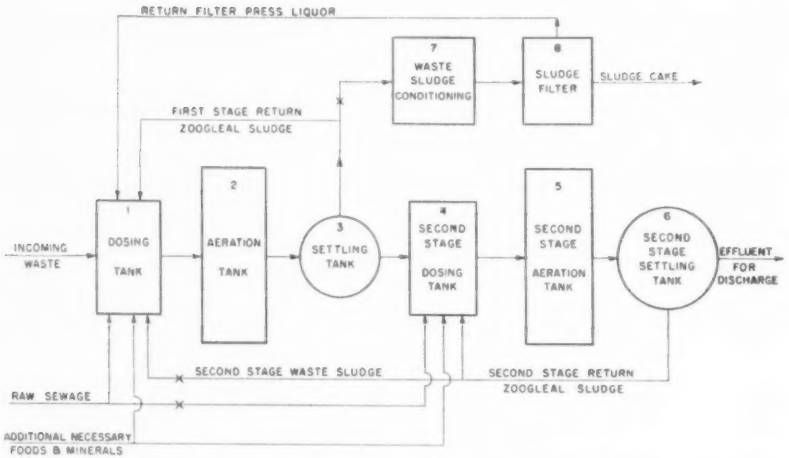

FIGURE 1.—Suggested flow diagram of a biological floc plant for treatment of wastes from nuclear operations.

tion period (probably 24 hr.), and into the first-stage settling tank 3. The settled zoogleal sludge from 3 would be returned to 1 and/or wasted by passage to the waste "hot" sludge conditioning tank 7 and to the sludge filter 8. The supernatant effluent from 3 would go to a second dosing tank 4 where additional necessary minerals, food, and return zoogleal sludge from the second-stage tank 6 are mixed with it. The second-stage mixed liquor would then be aerated for the additional required period in a second-stage aeration tank 5, the mixed liquor effluent from 5 being settled in tank 6. The settled zoogleal floc sludge from 6 is returned to the second-stage dosing tank 4 and/or wasted into the first-stage dosing tank 1. The supernatant effluent from the second-stage settling tank 6 should be satisfactory for discharge into a stream, or it could be given further treatment on slow sand filters, if necessary. It will be noted that drying the sludge after filtration is not contemplated in this plan, because dust from dried sludge carrying the concentrations of alpha emitters indicated earlier would be a serious hazard.

It is suggested that the safest manner of disposing of the wet sludge cake as it is removed from the filter press is to bury it in a properly located and protected dumping ground. All filter press liquors would, of course, be returned to the first dosing tank 1 to go through the process again. This scheme of treatment seems complicated when compared with simple domestic sewage treatment by activated sludge, but its principles are sound and there seems to be no apparent reason why it should not be successful. Operation of a plant of this kind must be under careful technical control and operating difficulties are to be expected.

Summary

The possibility of the treatment of wastes from nuclear fission operations by controlled biological processes has been reviewed. On the basis of experience and fundamental studies of the trickling filter and activated sludge processes, it seems that a modification of the activated sludge process is most

promising for treatment of such wastes. This process may be defined as a bio-chemical oxidative assimilation reaction by means of an activated sludge characterized by massive colonies of zoogleal bacteria having gelatinous matrices with tremendous surface areas that are capable of absorbing radioactive materials. It has been demonstrated at Los Alamos that more than 95 per cent of a long half-life alpha emitter in concentrations up to 1.4 micrograms per liter may be successfully removed from the liquor and transferred to the zoogleal sludge by aeration with activated sludge. Study of the Los Alamos experiments suggests that a well operating, two-stage, counter current flow, zoogleal floc process can be expected to remove 99 per cent of the plutonium from wastes, and produce an effluent that should approach a tolerance limit of 0.001 microgram per liter.

Many problems are apparent. Studies of tolerances of zoogleal sludges to the radioactive and other toxic ions contained in these wastes, as well as studies of the need for supplementary nutrients, including minerals, that may be necessary to develop active zoogleal sludges of proper characteristics, remain to be made before a successful plant can be designed and built. Studies on the various phases of this problem are underway at Oak Ridge, Tenn., Los Alamos, N. Mex. and Cincinnati, Ohio.

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Stream Pollution

A NOMOGRAPHIC SOLUTION OF THE OXYGEN SAG EQUATION

By H. W. Streeter

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One of the principal deterrents to the wider use of the oxygen "sag" equation in connection with stream sanitation problems has been the mathematical complexity of its solution. Although ingenious simplifications of the formula have been proposed, notably by Fair (1) and his co-workers, it has remained to a large extent a classroom problem, rather than the practical working tool it should be in order to realize its full usefulness as was originally intended. In order to facilitate its application, a nomographic method of solving the formula is presented in this brief explanatory paper. It is the writer's hope that presentation of the accompanying nomographs will stimulate both a more general use of the formula and further efforts to improve the nomographs themselves.

The equation of the oxygen sag curve, as originally derived (2), is:

$$D = \frac{L_a k_1}{k_2 - k_1}(10^{-k_1 t} - 10^{-k_2 t}) + D_a (10^{-k_2 t}) \quad (1)$$

in which D is the dissolved oxygen saturation deficit, in p.p.m., at any time, t, from the initial point; D_a is the initial D.O. saturation deficit, in p.p.m.; L_a is the initial total first-stage B.O.D., in p.p.m.; and k_1 and k_2 are coefficients defining specific rates of deoxygenation and reoxygenation (reaeration) in the stream. Although the time, t, may be measured in any units, it usually is expressed in days. The numerical values of k_1 and k_2 depend on the units in which t is expressed.

In order to determine the critical minimum point of the oxygen sag curve, it is first necessary to derive an expression for t_c, the time to this minimum point, and formulate the value of the minimum D.O. at this point in terms of D_c, the saturation deficit. The equation for t_c may be derived by differentiating Equation 1 with respect to time and placing the resulting expression equal to zero. Thus,

$$t_c = \frac{1}{k_2 - k_1} \times \left[\log \frac{k_2}{k_1}\left(1 - \frac{D_a (k_2 - k_1)}{L_a k_1}\right)\right] \quad (2a)$$

By denoting the quantity $\frac{L_a k_1}{k_2 - k_1}$ by the symbol a, and the fraction $\frac{k_2}{k_1}$ by the symbol f, which Fair (1) defines as the self-purification constant, Equation 2a may be reduced to the form

$$t_c = \frac{\log f \left(1 - \frac{D_a}{a}\right)}{k_2 - k_1} \quad (2b)$$

Using the symbols previously defined, the minimum D.O. (the maximum saturation deficit) may be expressed as

$$D_c = \left(\frac{L_a}{f}\right) 10^{-k_1 t_c} \quad (3)$$

Three series of nomographs have been devised for solving Equations 1, 2b, and 3, respectively. These nomographs are of the Z type, being simple and adaptable to successive multiplica-

tions and divisions of the various terms in the equations. The general method of operating a nomograph of the Z type is as follows. The left-hand and diagonal limbs show the scales of two quantities to be multiplied or divided by each other. Their product, or quotient, is shown in the scale on the right-hand limb. By running a straightedge through the known quantities on their proper scales, the result is read off by the intersection with the scale on the right-hand limb. In some cases, this result may be transformed directly into some function of it by using a logarithmic or some other functional scale instead of a linear one.

Determination of *D*

In Figure 1 are given nomographs for solving Equation 1, divided into three sets of scales denoted as Scale 1, Scale 2, and Scale 3. In order to apply these nomographs, it is necessary first to compute the numerical value of a, which remains constant for a given solution of the curve. It is also desirable to set up a simple tabulation of seven columns on a separate sheet, as illustrated in the upper right-hand corner of the chart. This tabulation will facilitate the use of the scales and save both time and possible errors. It will result in a series of values of D corresponding to any series of assumed values of t from the initial point of the curve. In practice, it is necessary to compute only four or five points in order to define the curve. For example, starting with D_a (at zero time), computations are made for assumed times of 1, 2, 3, 5, and 10 days, and the results tabulated as shown.

The operation of the scales is briefly as follows: Scale 1 gives values of the function 10^{-kt} for assumed values of either k_1 or k_2, which are set down, respectively, in Columns 2 and 3 of the tabulation, and their difference in Column 4. Scale 2 gives values of the product of this difference and the quantity a, the product being set down in Column 5. Scale 3 gives the product $D_a(10^{-k_2t})$, which is set down in Column 6. The sum of the values in Columns 5 and 6 then is equal to D, which is set down in Column 7. In order to illustrate the use of the scales, an example is shown in Figure 1 by broken lines and directional arrows, assuming the same data as in the example given by Phelps (3). Aside from the initial calculation of the quantity a, the computations incidental to these operations can readily be done mentally. For purposes of further illustration Table I is a full tabulation of data for five D-points on a curve, based on the same data as assumed in the chart. The entire operation for a given curve should consume not more than 15 or 20 minutes, once the operator has become familiar with the scales. If more points are required, they readily can be added to the tabulation by assuming shorter time intervals.

Finding Critical Point

Although the operation above described will usually define the oxygen

TABLE I.—Illustrative Tabulation of Points on Oxygen Sag Curve as Obtained from the Data Given in Figure 1

Time, t (days) (1)	10^{-k_1t} (2)	10^{-k_2t} (3)	$10^{-k_1t}-10^{-k_2t}$ (Col. 2 − Col. 3) (4)	Col. 4 × a (5)	$D_a(10^{-k_2t})$ (6)	D (Col. 5 + Col. 6) (p.p.m.) (7)
1	.79	.56	.23	2.3	1.1	3.4
2	.63	.31	.32	3.2	0.6	3.8
3	.50	.18	.32	3.2	0.4	3.6
5	.32	.06	.26	2.6	0.1	2.7
10	.10	.00	.10	1.0	0.0	1.0

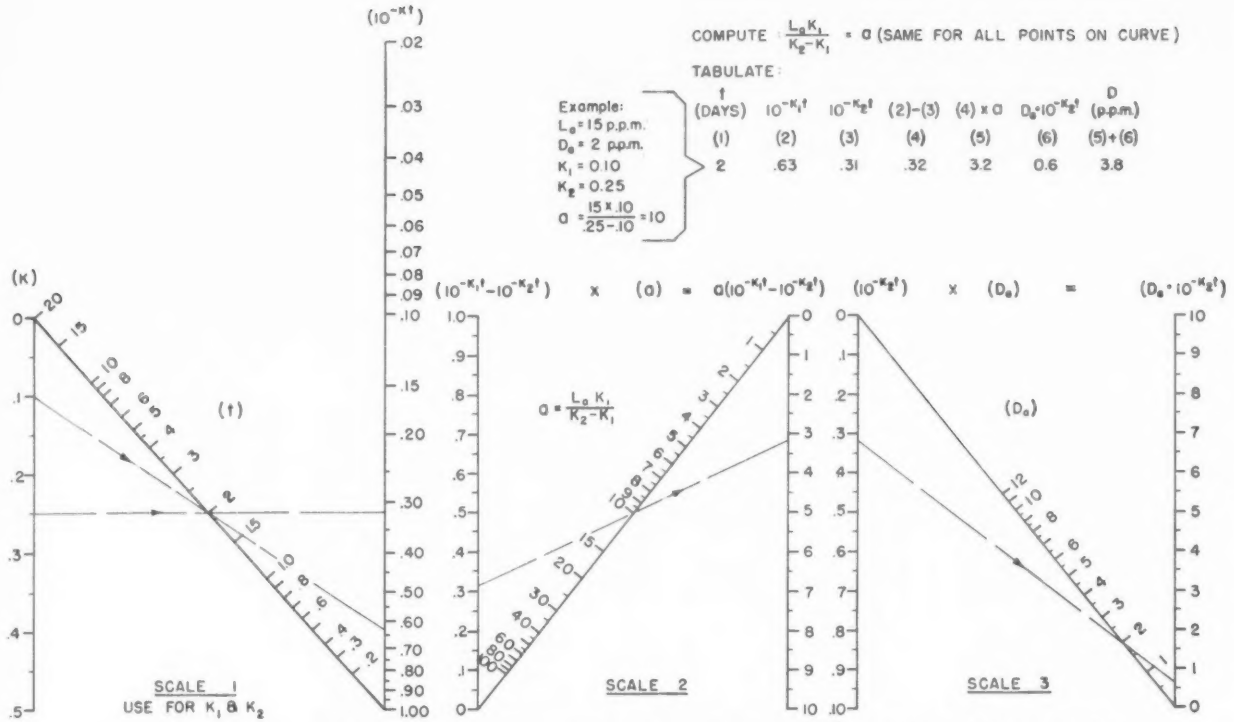
COMPUTE $\frac{L_a K_1}{K_2 - K_1} = a$ (SAME FOR ALL POINTS ON CURVE)
TABULATE:
Example:
L_a = 15 p.p.m.
D_a = 2 p.p.m.
K_1 = 0.10
K_2 = 0.25
$a = \frac{15 \times .10}{.25 - .10} = 10$
t (DAYS) | $10^{-K_1 t}$ | $10^{-K_2 t}$ | (2)-(3) | (4) x a | $D_a 10^{-K_2 t}$ | D (p.p.m.)
(1) | (2) | (3) | (4) | (5) | (6) | (5)+(6)
2 | .63 | .31 | .32 | 3.2 | 0.6 | 3.8
(10^{-Kt})
(K)
(t)
$(10^{-K_1 t} - 10^{-K_2 t})$ x (a) = $a(10^{-K_1 t} - 10^{-K_2 t})$
$(10^{-K_2 t})$ x (D_a) = $(D_a \cdot 10^{-K_2 t})$
$a = \frac{L_a K_1}{K_2 - K_1}$
(D_a)
SCALE 1
USE FOR K_1 & K_2
SCALE 2
SCALE 3

FIG. 1: NOMOGRAPH FOR SOLUTION OF OXYGEN "SAG" EQUATION: $D = \frac{L_a K_1}{K_2 - K_1} (10^{-K_1 t} - 10^{-K_2 t}) + D_a \cdot 10^{-K_2 t}$

sag curve sufficiently well to show a fair approximation of its minimum point, it often is desired to study this point alone in relation to various stream loadings, or to wastes treatment requirements necessary to meet some assumed reserve oxygen standard in the stream. For this purpose, a second series of nomographs has been worked out (Figure 2).

In Figure 2, Scales 1, 2, and 3 are intended to give a solution of Equation 2b for t_c, the time to the critical minimum point of the curve. The scales are arranged so as to facilitate a continuous operation from left to right, starting with Scale 1, as shown by the example and the designations above the scales. The same data has been assumed as in Figure 1.

The operations in Scales 4, 5, and 6, which are similarly illustrated by a broken line assuming the same data, are almost self-evident. The only scales needing explanation are those for the function $10^{-k_1 t_c}$, which is logarithmic in the right-hand limb of Scale 4, but linear (as a conversion scale) in the adjacent left-hand limb of Scale 5. This conversion is necessary in order to operate the multiplication in Scale 5. The result, D_c, is given in the right-hand limb of Scale 6. In order to show each step in the entire operation from Scale 1 through Scale 6, the quantity represented by each scale is given at the top, and the particular step of multiplication or division is indicated by a proper sign. In general, the operation requires only 2 or 3 minutes, once the user has become familiar with the scales.

It will be noted that the nomographs give results only to the first decimal place—that is, to the nearest 0.1 p.p.m. for D and D_c, and the nearest 0.1 day for t_c. This is usually a sufficient degree of precision for ordinary purposes. However, if greater refinement is desired, the results can be checked by slide-rule computation. In some of the scales, the reading error may be about 0.1 plus or minus, but this is a relatively small error when compared to those usually involved in the determination of the various elements making up the three equations.

The determination of these elements is beyond the scope of this paper, but has been discussed in considerable detail in two papers published in THIS JOURNAL in March and May, 1935 (4), and in other publications dealing with the subject (3) (5) (6). In assigning values to the rate coefficients, k_1 and k_2, care should be taken to correct them to the stream temperature at which the computation is to be made. Where stream data are available, observed changes in B.O.D. should be corrected for the effects of intermediate inflow, either of pollution or of dilution, in order to obtain a proper value for L_a (4). In some cases of this kind, where the normal course of the oxygen sag curve is disturbed by local pollution or dilution, it is often desirable to divide the entire stream stretch into several sections, readjusting both L_a and D_a at each section. The nomographs afford a rapid and convenient means of carrying out the re-calculations necessary in such cases.

Limiting B.O.D. Load

The nomographs in Figure 2 may be utilized, if desired, to estimate the limiting B.O.D. load on a stream which would maintain any desired minimum dissolved oxygen content under whatever temperature and other conditions might be assumed. Two methods are available for making such an estimate, the choice depending on individual preference. One method consists of assuming at least three trial values of L_a, covering a sufficiently wide range to include the value sought, and from each assumed value obtaining a resulting value of D_c by an operation similar to that illustrated in the chart. From a simple linear plot of the values of L_a against the values of D_c thus obtained, a very close approximation to the cor-

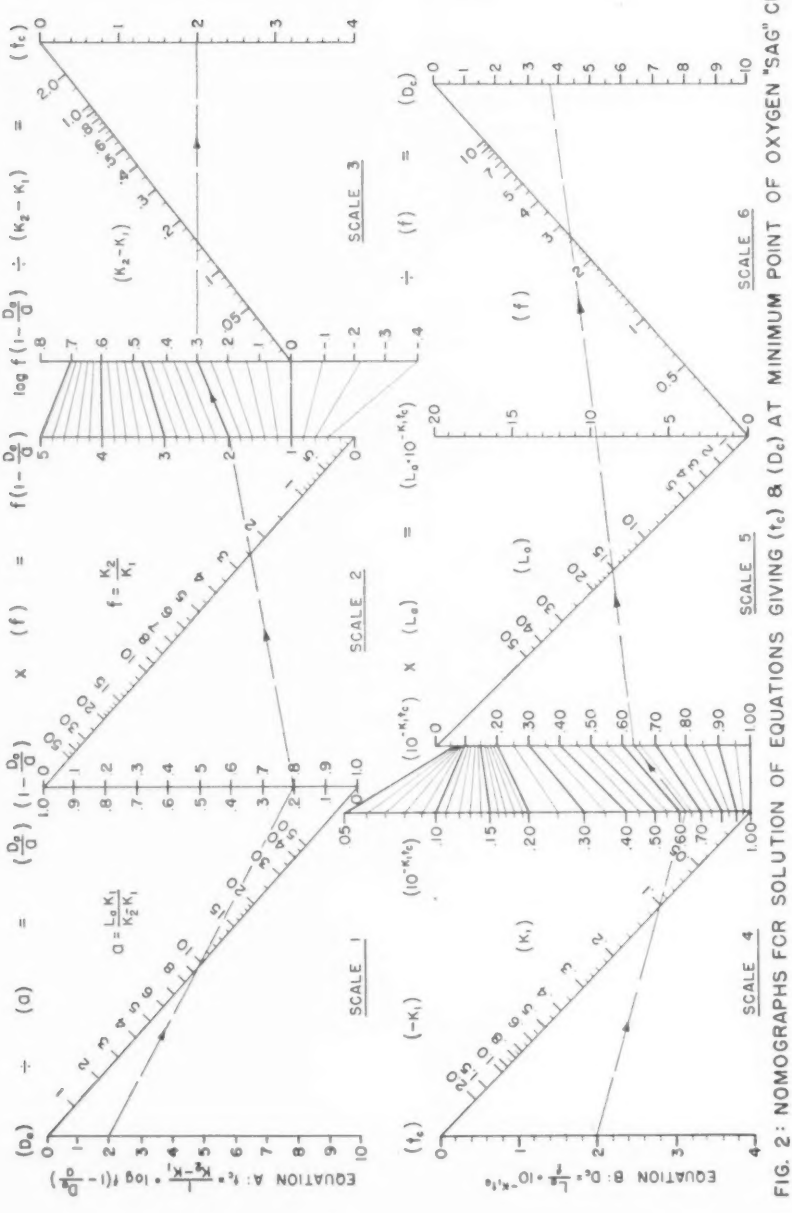
EQUATION A: $t_c = \frac{1}{K_2 - K_1} \cdot \log f\left(1 - \frac{D_a}{a}\right)$
EQUATION B: $D_c = \frac{L_a}{f} \cdot 10^{-K_1 t_c}$
SCALE 1
SCALE 2
SCALE 3
SCALE 4
SCALE 5
SCALE 6
$a = \frac{L_a K_1}{K_2 - K_1}$
$f = \frac{K_2}{K_1}$

FIG. 2: NOMOGRAPHS FOR SOLUTION OF EQUATIONS GIVING (t_c) & (D_c) AT MINIMUM POINT OF OXYGEN "SAG" CURVE

rect L_a would be located at a point on the plotted line corresponding to the prescribed limiting value of D_c at the assumed stream temperature. Although this method involves repeated operations on the nomographs, it is not laborious and requires little time.

An alternative method can be followed when existing conditions in a stream with respect to B.O.D. load and minimum D.O. content have been well established by observation, and it is desired to ascertain the extent to which the present load should be decreased, or may be allowed to increase, in order to meet a given minimum oxygen standard. It involves, first, assuming for trial purposes that the function $10^{-k_1 t_c}$ in Scale 5 will be approximately the same at the adjusted B.O.D. as under existing load conditions. Actually, this function will vary within quite narrow limits with a considerable variation in L_a, unless the value of k_1 changes materially under the adjusted load.

The first step in the operation is to start with the desired limiting value of D_c in Scale 6, projecting lines backward through this and Scale 5 to the proper value of $10^{-k_1 t_c}$ as previously determined for the present stream condition. The intercept on the diagonal scale in Scale 5 will give a new trial value of L_a, and hence a new value of a in Scale 1. This is then checked by the usual left-to-right operation through Scales 1 to 6. If a slightly different value of D_c than the one sought is thus obtained, L_a may be readjusted upward or downward for a second trial, noting that it will vary, in narrow range, roughly in proportion to D_c. In these check operations, a slightly different value of $10^{-k_1 t_c}$ will be obtained in Scale 5, but it should be used whatever it may be.

An example of this operation may be worked out from the data given in connection with Figures 1 and 2, which give a value of D_c equal to 3.8 p.p.m. based on an assumed L_a of 15 p.p.m. If it be desired to determine what reduction in L_a would be necessary in order to limit D_c to 2.7 p.p.m. (the equivalent of 6.5 p.p.m. of D.O. at a stream temperature of 20° C.), a close approximation to this figure may be obtained in the first trial check, with L_a at 10.5 p.p.m. as given in Scale 5. A slight adjustment of this figure to 10 p.p.m. gives a closer approximation to 2.7 p.p.m. as the correct D_c value. The result thus obtained would indicate that the B.O.D. load originally assumed (that is, 15 p.p.m.) would have to be reduced by about one-third in order to meet the minimum D.O. requirement of 6.5 p.p.m.

Because of the relatively small scale necessary in order to print the nomographs as herein presented, it would be desirable for those who may have frequent use of them to enlarge them to about double their page-size scale. This would give a chart about 10 by 16 in., a convenient size both for routine use and for folding into an ordinary ring note book.

The author hopes that the publication of these nomographs will stimulate the more general use of the oxygen sag formulas, wherever they may be applicable to the solution of practical problems. The equations are sound and include all of the essential variables, which likewise have been included in the nomographs. If those who are responsible for the operation or design of sewage treatment plants can be encouraged to devote more study to the streams receiving their effluents, the nomographs will have accomplished a useful purpose.

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ALMON LAWRENCE FALES (1876–1949)

Almon Lawrence Fales, Boston consulting sanitary engineer, died at his home in Newton Centre, Mass., August 19, 1949, after an illness of several months.

Mr. Fales was born in Medway, Mass., January 6, 1876. He graduated from the Worcester Polytechnic Institute in 1898, with the degree of Bachelor of Science in Chemistry. From 1898 to 1913 he was connected with the sewage purification works of Worcester, Mass., rising from assistant chemist to superintendent and director of testing laboratories. In 1913 he joined the consulting engineering firm of Metcalf and Eddy, Boston, from which he retired as an active partner in 1948 due to ill health. He retained his connection with the firm as a consultant until his death.

Mr. Fales was one of the country's leading authorities in the field of sanitary engineering, particularly in stream pollution abatement, sewage purification and industrial wastes treatment. Among his clients were some of the largest municipalities and industrial concerns of this country and Canada. In both world wars he served the U. S. government as a consultant on sewage disposal methods at army camps and treatment of wastes from ordnance plants.

He was the author of many articles in the technical and scientific press, and was a member of the American Society of Civil Engineers, the Boston Society of Civil Engineers, the American Water Works Association, the American Chemical Society, the New England Water Works Association, and the New England Sewage Works Association. As a member of the "Committee of 100," the creative group working toward establishment of the Federation, Mr. Fales took an active part in early formation of the present international organization.

Mr. Fales is survived by his wife, Clara Alice (Blood) Fales, and three daughters, Doris Edna Fales, Virginia Blood Fales, and Marion Elizabeth (Fales) Dietz.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

LONG-RANGE ROOT CONTROL

The selection of types of street trees ordinarily does not come within the purview of the superintendent of sewers. Nevertheless, he should be deeply interested in this aspect, for it is usually these trees that cause his root stoppage problems. To use special sewer construction near trees is only half the solution; the other half is to limit root growth as much as possible at the source—the tree—by seeing to it that new or replacement plantings are made only with species having favorable root habits.

As the various elm diseases reduce the numbers of this popular street tree it behooves the sewer superintendent to assert himself in the matter of types and species planted as replacements. In addition, the residential development of new urban and suburban areas poses the companion problem of controlling new plantings in those subdivisions so that foreseeable root troubles can be avoided.

In most communities street trees come under the jurisdiction of either the street department or the park department. Here, then, is the point where cooperative action in regulatory policy is most likely to be fruitful. In any event, to acquaint the city council with the high cost of root penetration into the sewers will be worth every minute spent on it, as the council also has a means of regulation in the issuance of street and utility permits for new real estate developments. If regulatory policy is not already established it should be among the first steps considered.

From the standpoint of root penetration, which trees are bad and which are good? The very elms whose loss has been deplored are water seekers whose roots will stop up sewers. So also are sycamores, silver or soft maples, poplars, and willows. In addition, the sycamore, mulberry, black locust, honey locust, ash, ailanthus, black walnut, and catalpa have other objectionable features in the form of shedding bark, over-ripe and decomposing fruits, a short leaf-bearing season, numerous suckers, and insect pests.

Omitting the smaller types of trees as unsuitable for street planting narrows the field considerably. Of all types of trees, those which stand out predominantly as having excellent character, great beauty, fairly rapid growth, long life, and good root habits —all desirable in street trees—are: tulip, sweet gum, hard maple, horse chestnut, basswood, pecan, red oak, pin oak, chinquapin oak, and bur oak.

Naturally, not all these trees are suitable in all climates or locations. Judgment based on local experience will have to be the final deciding factor in selection. However, a little time spent now in deciding what species are to be allowed will pay rich dividends if the selection reduces future root stoppages to a minimum.

H. P. O.

WASTE ACTIVATED SLUDGE THICKENING AT HAGERSTOWN, MD.*

By Don K. Croft

Chemist, Sewage Treatment Plant, Hagerstown, Md.

The basic operating problem at Hagerstown has been handling of the thin excess sludge from the activated sludge process. The original plan for handling the excess solids was to waste them directly into the preliminary settling tanks. The result was an increase of solids in the preliminary effluent as compared to the raw solids entering the tanks.

This condition was caused, in part, by the high volatile content of the sewage solids and by the somewhat high velocity in the preliminary tanks, particularly during peak flows.

Sewage and Sludge Characteristics

The sewage is nearly normal domestic sewage, except for the high volatile content of the solids. The average solids content is 155 p.p.m., and the B.O.D. is 189 p.p.m. The volatile content of the solids ranges from 7.7 to 89.6 per cent, with an average of 84.4 per cent. Temperature varies from 56° to 76° F. During 1948 the average flow was 4.35 m.g.d.

The excess activated sludge averages 0.6 per cent solids, the volatile content being slightly lower than on the raw solids. The quantity of this sludge to be wasted averages 90,000 g.p.d.

The mixed raw and activated sludge removed from the preliminary settling tanks averages from 3 to 4.5 per cent solids, with pH ranging from 5.6 to 6.2. For 1948, the average volatile content of the solids was 81.8 per cent. Approximately 2,200 cu. ft. of this mixed sludge is drawn from the tanks daily, with 1,400 cu. ft. being dewatered on vacuum filters and 800 cu. ft. being digested.

The following is a typical analysis, taken from the plant report of August, 1947. It is average for that time of year.

	Solids	B.O.D.
Raw sewage (p.p.m.)	143	172
Primary effluent (p.p.m.)	234	—
Aeration tanks (p.p.m.)	1,450	—
Final effluent (p.p.m.)	13	27
Removal, raw to final (%)	90	84
Prelim. sludge (cu. ft.)	2,900	
Solids (%)	3.64	
Volatile (%)	82.5	
pH	6.1	
Digested sludge		
Volatile (%)	64.4	
Solids (%)	2.27	
pH	7.3	

Sludge Handling Facilities

The old preliminary tanks (Figure 1) are of the rectangular type, each 16 by 75 ft. with a 10-ft. sewage depth. The two tanks have a combined detention period of 1 hr. at a 4-m.g.d. flow, at which rate the velocity is 1.25 ft. per min. The surface loading is 1,670 g.p.d. per sq. ft. and the overflow is 143,000 g.p.d. per foot of weir.

There are two heated digesters of the multi-stage type. The primary digester has a fixed cover; the secondary, a floating cover providing 25,000 cu. ft. of gas storage. The total digester capacity is 101,000 cu. ft. Digested sludge, which averages from 2 to 3 per cent solids, is handled on sand beds having a combined area of 64,800 sq. ft.

Waste Activated Sludge Concentration

During the past 15 years a number of schemes have been tried to improve

* Presented at 1949 Annual Meeting, Maryland-Delaware Water and Sewerage Association; Hagerstown, Md.; April 28–29, 1949.

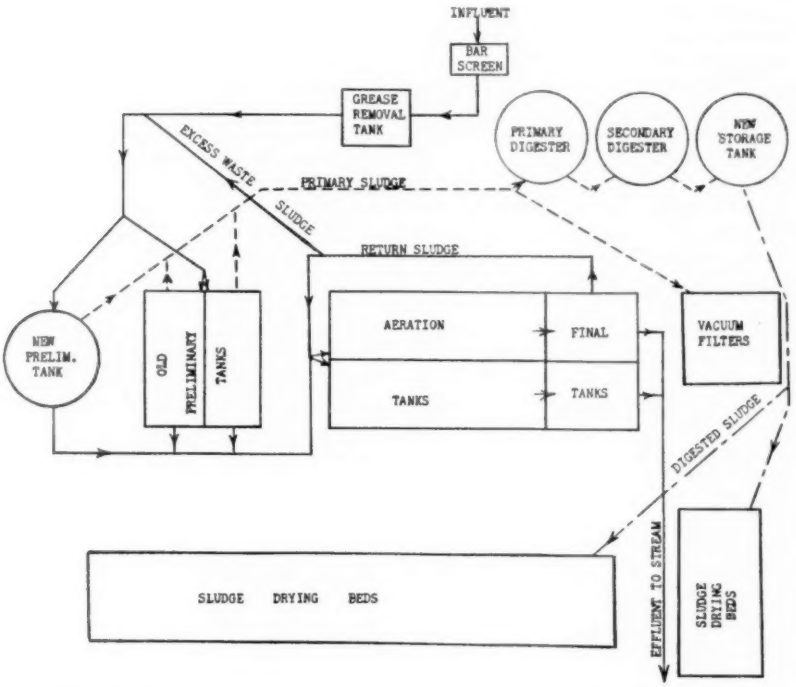

FIGURE 1.—Flow diagram of the Hagerstown, Md., sewage treatment plant.

the settling of the excess sludge in the preliminary tanks. Iron salts in the various forms improved the settling only slightly. The cost would not justify their use. Chlorine added to the return sludge did not prove to be helpful; neither did pre-chlorination. A sludge thickener having a 23,600-gal. volume and capacity for handling 95,000 g.p.d. was installed in 1939. Nevertheless, the sludge would not settle to more than 1½ to 2 per cent solids. This thin sludge overloaded the digesters and could not be handled on vacuum filters. Consequently, use of the tank as a thickener for excess sludge was discontinued.

The only method found to be helpful was treatment of waste sludge with lime at a rate of 4 to 5 lb. per 1,000 gal., then aerating, using about 0.1 cu. ft. of air per gallon. This method has been used until this year.

With the lime treatment, from 30 to 40 per cent of the raw and activated solids were removed in the preliminary tanks. The balance of the solids were carried over to the aeration tanks.

Recirculation (from primary, to aeration, to final, and back to the primary) caused a gradual build-up of solids within the plant. This was controlled by increasing the rate of return sludge and using more lime on the excess. An illustration of this is taken from plant reports. In May, 1948, the aeration tanks were carrying 1,480 p.p.m.; the return sludge, 6,650 p.p.m. In October, the aeration tanks were carrying 2,100 p.p.m.; the return

sludge, 8,340 p.p.m. The per cent removal from raw to final remained in the high eighties.

Due to the high flow in the receiving stream, the plant is permitted to operate from November through March without returning sludge, but with aeration. If this was not practiced the build-up of solids would become serious, through a decrease in the over-all plant removal.

Primary Sludge Problem

The second phase of the sludge problem is what to do with 3 to 4 per cent sludge from the preliminary tanks. As previously stated, about 60 per cent of this sludge is filtered. Filtering costs average about $17 per ton of dry solids in 1948. The raw cake from the filters is pretty potent, to say the least. It is hauled by trucks to farmlands for fertilizer and great care must be exercised in selecting areas that will not be offensive to neighboring farms. This is also a problem.

The sludge that is digested decreases in solid content instead of concentrating. Volatile reduction is good, averaging more than 60 per cent, but the 2 to 3 per cent sludge from the digesters tends to overload the sand beds.

It should be pointed out that 600 cu. ft. of 5 per cent sludge contains the same amount of solids as 1,000 cu. ft. of 3 per cent sludge. Therefore, if it were possible to concentrate the sludge in the primary settling tanks from 3 per cent to 5 per cent, the volume to be filtered and digested would be reduced by 40 per cent. In turn, it is reasonable to assume that sludge going to the digesters at 5 per cent solids should finish at 4 per cent instead of 3 per cent, thereby reducing the digested sludge volume to the beds by 25 per cent.

Plant Improvements

With this in mind, R. T. Regester, consulting engineer, was engaged to make a study of the plant. His report, submitted in 1946, recommended enlargement of the primary settling capacity, provision of sludge storage for digested sludge, and additional air capacity for aeration. The tanks were built and put in service April 1, 1949 (see Figure 1). The blower for the additional air capacity is being installed.

The new primary settling tank is of the circular type, 55 ft. in diameter, and provides a 10 ft. depth of sewage. Mechanical sludge and scum removal equipment is supplied. With this tank in service the combined preliminary detention period is doubled, providing 2-hr. detention at a 4-m.g.d. flow rate. The velocity in the rectangular tanks is reduced from 1.25 to 0.63 ft. per min. and the circular primary tank has a velocity of 0.23 ft. per min.

Excess solids are wasted directly into the raw sewage pipeline, where they are thoroughly mixed with the raw sewage before entering the primary tanks.

It is believed that the increased detention period, with the resulting lower velocity, will permit the excess solids to settle, thus giving a reduction of solids in the preliminary effluent over the raw solids in the influent. Again, with the lower velocity the solids should settle to a denser sludge, with the solids content of the preliminary sludge increasing by at least 1 per cent.

With these improvements, instead of a build-up of solids within the plant a better balance can be maintained in the aeration tanks with fresher solids and a decrease in the amount of excess solids to be wasted into the primary settling tanks.

The 2,800-c.f.m. blower now being installed is of the positive displacement type. The existing blowers provided 1 cu. ft. of air per gallon of sewage at a 4-m.g.d. flow rate, but during the periods of daily peak flows (5 to 6 m.g.d.) insufficient air was available for good aeration. With the new

blower in service ample capacity will be available to aerate peak flows at well over 1 cu. ft. per gal. The additional air should produce a better dissolved oxygen content in the mixed liquor and in the final tanks. This should allow concentration of the sludge in the final tanks, so that the return sludge can be increased from 0.6 per cent to 0.8 or 0.9 per cent solids.

The sludge storage tank is designed to be converted to a digester at a future date if desired. The 50,000-cu. ft. tank is 50 ft. in diameter, 25 ft. deep at the wall and has a conical bottom. Supernatant can be drawn off at three levels. The purpose of this tank is not only to store digested sludge, but also to serve as a thickener. Inasmuch as all of the digested sludge is dried on sand beds, the digesters cannot be loaded to their capacity during periods of poor drying weather. The storage tank will remedy this condition.

Anticipated Benefits

It has been found that the digested sludge will thicken when allowed to stand in an open tank for several weeks. If 2½ per cent sludge is drawn into the storage tank it will settle and thicken to at least 4 per cent, which means that for every 1,000 cu. ft. of sludge put into the tank, 375 cu. ft. of supernatant can be drawn off. This leaves 625 cu. ft. of sludge to be handled on the beds, or 37.5 per cent less volume. To express this in relation to bed area, the reduction of water per cubic foot of sludge would be equivalent to an increase in bed area of 37.5 per cent. These calculations are based on the 2½ per cent sludge now drawn from the digesters. When the improvement in efficiency of the primary treatment is realized, the efficiency of the digesters should improve. This in turn will give a greater equivalent increase in bed area.

Although the new tanks have been in service only a short time, it is apparent that the desired efficiency will be realized. The averages from three full weeks of operation with the new tanks in service show 138 p.p.m. solids in the raw sewage, and 75 p.p.m. solids in the primary effluent, or 45.7 per cent reduction. For the corresponding period in 1948 raw solids averaged 103 p.p.m., and primary effluent solids averaged 178 p.p.m., an increase of 75 p.p.m. Digested sludge drawn from the new storage tank to the beds showed 5.3 per cent solids. Sludge drawn from the digester to the beds in April, 1948, contained only 2.6 per cent solids.

DISCUSSION

By Robert T. Regester

Consulting Engineer, Baltimore, Md.

Mr. Croft has given, from the operator's viewpoint, a concise explanation of the perplexing problem at the Hagerstown plant, and a description of the recent improvements made to remedy the condition. Perhaps the engineering generalities of the sewage treatment situation, as related to the growth of this progressive city, also will be of interest.

The existing Hagerstown plant was enlarged in 1933 to serve 40,000 population, as then predicted for the year 1945. The design was based on a per capita sewage flow of 100 g.p.d. For the past 8 years, however, the average per capita flow has exceeded this design value. Accordingly, the nominal plant capacity of 4 m.g.d. was actually reached about 1941, when the city's population was less than 34,000. Since that time the plant has operated

slightly beyond capacity, as indicated by the average daily sewage flow. The time has arrived when adequate provision should be made for further enlargement of the sewage treatment works to serve at least until 1960, when it is expected that the average flow will be 6 m.g.d., or 150 per cent of the existing plant's capacity.

As a principal basis for the recent study, the monthly records of operation (for the period 1933 to 1945) were plotted in diagram form for comparative analysis. The actual performance of the rectangular preliminary tanks was strikingly indicated during the seasons of complete treatment, when excess activated sludge is wasted to the incoming raw sewage for removal in the tanks. Since about 1936, the settled sewage leaving the tanks has had a greater suspended solids content than the raw sewage to be treated in the plant, with the maximum monthly increase varying from 50 to 200 per cent of the raw-sewage solids content. Even in the seasons of partial treatment, the removals of suspended solids from raw sewage alone have been well below acceptable efficiency. These deficiencies in sedimentation were likewise reflected in the B.O.D. of the settled sewage. In this case, the increase above the raw-sewage B.O.D. varied from 25 to 70 per cent, mostly during the seasons of complete treatment.

It was concluded from a careful analysis of the monthly operating data that (1) the existing preliminary tanks have certain inherent settling limitations that seriously restrict their capacity when handling waste activated sludge; (2) the recirculating load of excess sludge solids soon becomes septic, from contact with the warm raw-sewage solids, and blanket rising of deposited particles results from gas bouyancy; (3) active decomposition of the sludge under warm conditions, as indicated by its low pH, indicates the necessity for more frequent regular removal of the accumulated solids; and (4) the weaker sewage accompanying heavy flows apparently has a retarding effect on septic action, probably because of less volatile matter and somewhat higher dissolved oxygen content than with the lower flows.

Grateful acknowledgment is made for the generous cooperation and assistance extended during the progress of the studies by C. W. Stump, Jr., former city engineer of Hagerstown, and his staff, including H. E. Rhodes, superintendent of the plant, and D. K. Croft, chemist.

IMPROVING SEWAGE TREATMENT PLANT OPERATION WITH NEW TYPE ELECTRONIC CONTROL

By Henry M. Fitch

Assistant Engineer, Engineering Dept., Seattle, Wash.

Control of sewage pumping plants has not advanced beyond the stage of simple float switches or other mechanical linkage systems employing bellows or mercury tubes and is a weak link in the design of plants of this nature. During the decade 1930–1940 Seattle, Wash., in connection with the interceptor sewer system, constructed 16 pumping plants, all of which were equipped with float type controls. This, together with the installation of types of pumps in many instances not suited for handling raw sewage, subsequently created a maintenance problem for the operating department. To make the best of these errors of design during the war and post-war period when ade-

quate trained personnel was not available, new methods had to be devised to relieve the labor requirements for pump station operation. As a result, Seattle is now using in its pumping stations electronic type controls not found in any other plants of similar importance in the United States. Comparison of these new controls with antiquated float types still being used in the design of new plants is like comparing modern cars with the Model T Ford.

A practical demonstration of the improvements made with this type of electronic control in a plant equipped with pumps not suited for raw sewage pumping and of wrong capacities for matching the existing flows has been given during the past two years at the Diagonal Way sewage treatment plant, which is Seattle's largest, and designed to give primary treatment to an average flow of 8 m.g.d. So far as is known, it is the first such application, and patent rights are pending.

The control (Figures 1 and 2) is approximately the size of a heavy-duty type float switch. However, it performs many functions simultaneously, in addition to its primary purpose of controlling the three pumps located in the plant. A control system of this type requires no floats, bellows, electrode, or thermal element in contact with the sewage; there are no moving mechanical linkages, aside from small electric relays. The control is pressure responsive in action from an air-bell suspended in the wet well. Precision, maintenance-free control has resulted since its installation.

Flows to the plant are generally in excess of the capacity of one pump and less than that of two pumps. The third pump is a spare unit for rotation or emergency use, but is always connected with the control. In the event of a mechanical failure which would allow sewage to gain access to the dry well, or to clog the pumping units, the control will automatically close the

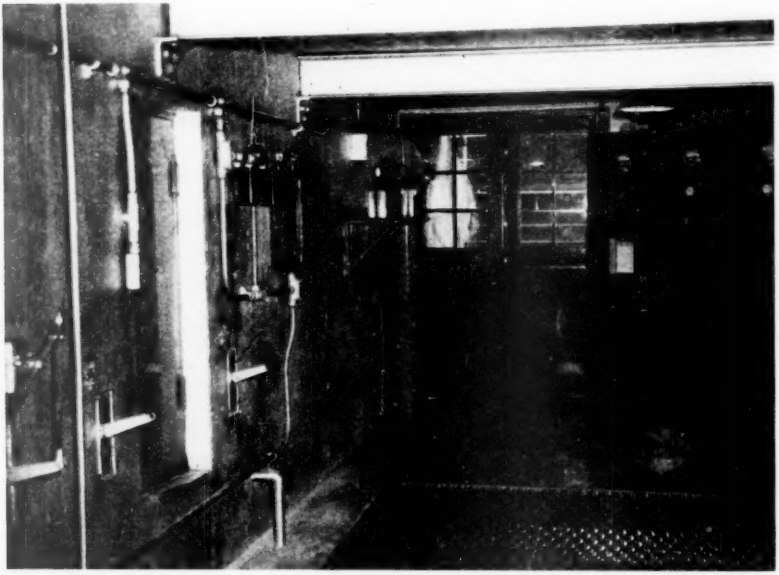

FIGURE 1.—General view of electronic type control in Seattle sewage pumping station.

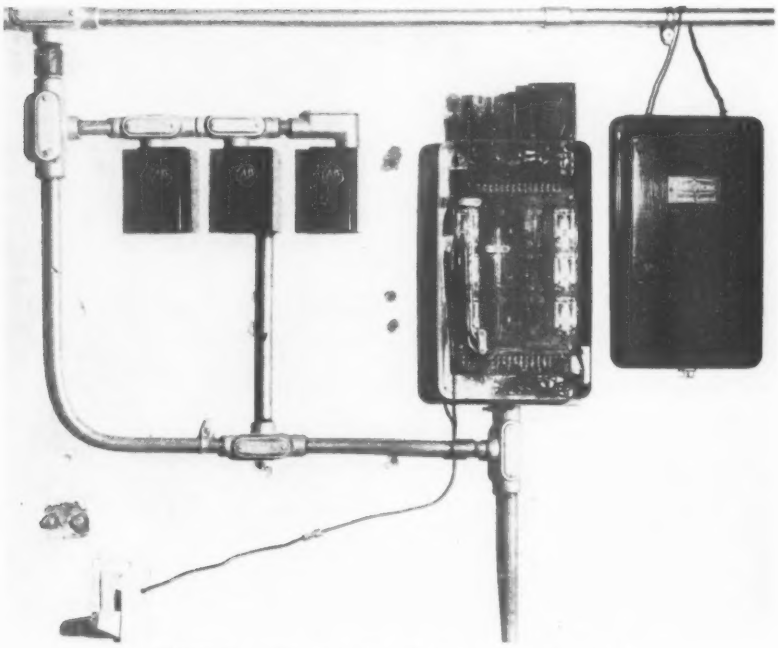

FIGURE 2.—Closeup view of electronic type control.

inflow gate and cut in the stand-by pump. Thus, there is positive protection of the operating equipment against flooding or excessive vibration.

The matching of pump capacities to flows for best operation was not possible with the original float control system. By taking advantage of the existing hydraulic conditions—that is, storage available in the feeding sewer—and coordinating with a system to control inflow into the wet well, the operation of this plant has been greatly improved. This is accomplished with only one actuating device that otherwise would require some 8 floats and assemblies, or complicated mechanical linkages and conduit wiring.

Figure 3 shows a flow graph obtained with the original float type controls installed in 1938. The sawtooth effect is the result of all three pumps having identical capacities. Figure 4 is a flow graph obtained after installation of the new control. It shows a continuously varying flow never falling below an efficient operating point or exceeding the designed capacity of the plant. Comparison of the data from the two flow graphs shows a saving of 140 kw.-hr. of power and 9.91 hr. of pumping time for 24-hr. operation to handle approximately identical flows. Had this type of control been installed in 1938 instead of floats, years of pumping time, plus wear, tear, and maintenance, would have been saved in the intervening years.

The improvement in flow through the plant on a continuous basis, as shown by Figure 4, is the result of using the sewer ahead of the plant as a storage reservoir to equalize the peaks of vari-

able flow. The storage allows operation of one or two pumping units on a constant depth basis in the wet wall. The water depth is maintained by a motor operated inflow gate operating off the control. Power saved, as indicated, is the result of selecting an operating depth in the wet well that will develop the rated horsepower of the motors driving the pumps. At their rated horsepower the pumps discharge more sewage constantly than they would if operated periodically under a varying depth as shown in Figure 3. This accounts for the reduction in operating time. A further saving in packing life was realized by the constant loading of the pumps. The life of a set of packing before use of the new control was approximately 800 hr.; now a set lasts about 3,000 hr. The saving in material and attention is considerable.

Septic conditions that previously developed in the feeding sewer have been eliminated by the inflow gate controlling the operation depth in the plant wet well. The checking and opening

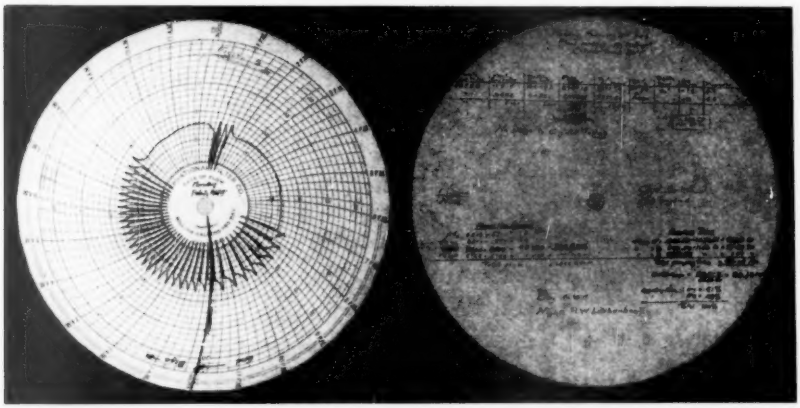

FIGURE 3.—Flow graph for 7.225-m.g.d. pumpage with float type controls.

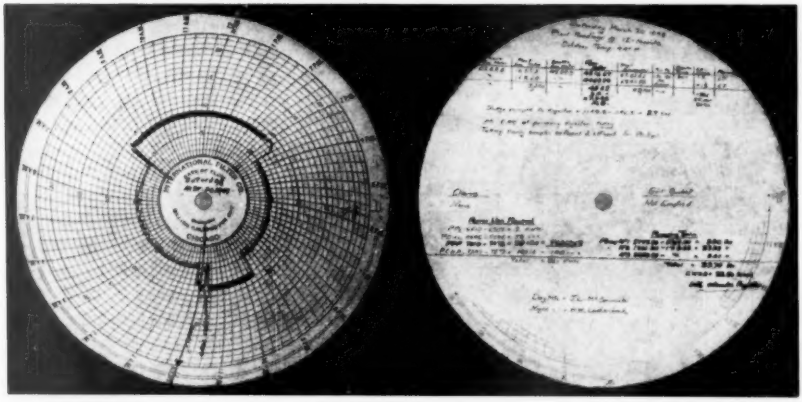

FIGURE 4.—Flow graph for 7.242-m.g.d. pumpage with electronic type control.

action of the inflow gate sets up a surf-like wave action in the sewer, constantly agitating any settleable material. When the pumps gain on the supply in the sewer until there is no control action by the inflow gate, which has attained a wide open position, a maximum velocity is attained sufficient to flush the sewer. An example of this feature is seen in the upper sector of the graph in Figure 4.

The feeding sewer is a combined system with no bar screens or sand removal facilities located ahead of the pumping plant. All waste materials carried in the sewage have to pass through the pumping units. Because the pumps in this instance are not open impeller types, it is desirable to maintain through the pumps satisfactory velocities with respect to their capacities for the longest time possible in order to prevent clogging by rags. Figure 4 shows this result.

The pumping plant discharges to a grit chamber equipped with mechanical grit removal and organic wash return. This unit will operate efficiently on a varying flow not exceeding 8 m.g.d. However, with the pumps operated by the old type controls only 0.75 cu. ft. of grit was removed in the grit chamber for each m.g. passed; with the new type pump controls grit removal is 6.70 cu. ft. per m.g.

The increase in sand removal was immediately reflected in the digester operation. In the past, 2 yr. has been the maximum operating time for the primary digester before draining was necessary for the removal of sand. Under present conditions, 10-yr. operation may be realized before a similar condition results, provided other factors remain constant. The reduction of sand carried in the sludge being pumped to the digester will also reduce piston wear in the sludge pumps. Better sand removal in the grit chamber also will reduce abrasion of the comminutor drums.

Operating histories of the new controls have proved that float type switches, bellows with mercury tubes, and others utilizing mechanical linkages, are obsolete for sewage pumping plant control, except as auxiliary units for emergencies. Sewage is a variable, highly contaminated fluid requiring the best methods for satisfactory maintenance-free control. Advantages of the electronic control are many, particularly when used for multiple functions.

In the application described, cumbersome complexity has been exchanged for simplicity with a single completely automatic unit. Nine of the city's sewage pumping stations are now equipped with the new control, and show results similar to the Diagonal Way installation. The remaining plants in the Seattle system will also be electronically controlled in the near future.

OPERATION AND MAINTENANCE AT HAYS, KANSAS *

By Roy Binder

Operator, Sewage Treatment Plant, Hays, Kansas

The sewage treatment plant at Hays, Kansas, of the trickling filter type with separate sludge digestion and gas utilization, treats an average flow of 1.25 m.g.d. Major processing units include two comminutors, a primary sedimentation tank, two trickling filters with rotary distributors, a final set-

* Excerpts from paper presented at 1949 Annual Meeting, Kansas Sewage Works Association; Hutchinson, Kans.; April 21–22, 1949.

tling tank, two digesters with fixed covers and stirring equipment and 16 open drying beds. Digester gas is used for heating the building and digesters; excess gas is burned in an incinerator.

The greatest problem from an operational standpoint has been caused by crankcase oil coming to the plant from garages and filling stations. Obviously, the oil had to be handled immediately and then steps taken to prevent further discharges to the sewers. Oil arriving at the plant wet well was pumped to the already oil-covered clarifier, as was also the oil-contaminated water used for washing down the wet well walls.

It was intended to skim off the oil in the clarifier. However, a considerable quantity escaped over the clarifier weir and was sprayed over the trickling filters. The oil coating on the filter stone, in combination with small amounts of suspended material in the influent, caused the filters to pond.

Several different methods of overcoming the ponding were tried. Jetting with water did little good. Forking of the ponded areas drained off the water, but within a day or two it would pond somewhere else. Taking the filter out of service for 24 hr. seemed only to produce odors. When it was realized that the clogging was only in the top 4 to 8 in. of the stone, the entire surface was loosened to that depth by forking. This proved highly successful, and the beds are now forked in this manner twice each year.

Continuation of the oil flow was remedied by the simple expedient of placing floats, made of 18-in. lengths of 2 by 6 painted white, in the manholes near each garage and filling station. During the installation period the newspapers carried notices and articles telling what was being done, and the penalty to expect if—when oil appeared at the plant—a check of the floats revealed the source of the oil. Since installing the floats 6 months or more ago, the crankcase oil problem has disappeared.

Few Digester Problems

Digester troubles at Hays have been few and far between, mostly as a result of following a few simple rules. These are:

1. Check the sludge pumping to eliminate pumping of excess liquid.

2. Check sludge withdrawals to eliminate depletion of the seed and the removal of sludge liquor.

3. Keep the pH in the digesters at 7.0.

4. Keep the digester temperature between 95° and 100° F.

5. Keep daily records of the pH, the depth of sludge in the digesters, when drying beds are filled and the amount, the digester temperature, and other pertinent data.

Problems arising from drawing too much liquid into the digesters have been solved by putting a time clock on the sludge pump. The clock is set to provide a certain time of pumping every 2 hr., depending on the amount of solids accumulated in the clarifier during the 2-hr. period. With the clock set properly, the drawing of too much liquid into the digesters is stricken off the ever-present list of items to remember.

The digesters are worked hard during the spring and summer months and a careful watch is kept on the pH. Full advantage is taken of good drying conditions on the open beds to draw the digesters down by the end of November, leaving just enough sludge for good seeding. By doing this very little sludge has to be drawn during the winter months, when withdrawal is difficult and drying is slow.

Trickling Filter Maintenance

Like most of the smaller secondary treatment installations the Hays plant uses trickling filters. The two 90-ft.

diameter units require little attention, their cost of operation is low, and they are seldom subject to disturbing factors that affect their efficiency. Therefore, outside of the oil trouble previously mentioned, filter problems have been confined to maintenance and fly control.

Filter flies have been a big problem. Several methods have been tried to get rid of them, some more effective than others. Burning with an air-pressured blow torch, as well as dosing with kerosene, creosote, chlorine, and ammonia, proved comparatively ineffective.

Spraying with DDT is the method now used, the dosage being 4 gal. of 5 per cent solution, made up by diluting 1 gal. of 20 per cent concentrate with 3 gal. of water. Every attempt is made to reach all breeding places at each spraying—near the end of April, June, and August. The weeds around the filters are mowed, then the flow in the distributor arms is cut off. Using a power sprayer, two men, each with 50 ft. of hose and a fan shaped nozzle, spray the stone, the distributor arms, the inside wall, the outside wall to the runoff point, and the weeds around the filter for a distance of 15 to 20 ft. With this procedure, fly troubles have been eliminated.

Distributor spray nozzles are cleaned each day by inserting a ¼-in. rod 30 in. long and bent at one end. About once a month a stiff brush is used to remove the crust-like substance that gathers around and under the nozzles, and the arms are flushed out with a spray nozzle under high pressure. Winter troubles resulting from ice formations at the center column of the distributors have been eliminated by plugging the openings nearest the center on each arm.

For cleaning the filter underdrains a ¼-in. steel cable is run back and forth a few times. Special attention is paid to keeping the effluent troughs or runways clean for good ventilation.

INTERESTING EXTRACTS FROM OPERATION REPORTS

"Anything a man needs in his business he is paying for whether he buys it or not."

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage Works Associations, Room 325, Illinois Bldg., Champaign, Ill.

Report on the Operation and Maintenance of the Easterly Sewage Treatment Plant, Cleveland, Ohio, for the Year 1947 *

By Walter E. Gerdel, *Superintendent*

Normal conditions and operations existed the entire year. The average daily flow of 104.0 m.g. represented an increase of 12.3 m.g. over the previous year, which, however, was abnormally low. The previous 5-yr. daily flow average of 96.2 m.g. was exceeded by 7.8 m.g., which represents an increase of 8.1 per cent. The extremely wet spring weather accounted for some of the increased flow, but normal increased water consumption in the area

* For previous extracts see This Journal, **12**, 3, 625 (May, 1940); **15**, 1, 99 (Jan., 1943); **18**, 1, 113 (Jan., 1946); **20**, 3, 551 (May, 1948).

served by the plant seems to be the main reason for the higher flow.

Continued real progress was also made in the pumping of sludge to the Southerly plant. The sludge pumped was the most concentrated ever delivered since this pumping operation was started in 1938.

Considerable time and effort have been given to the larger replacement and maintenance projects, which either have been deferred because of the war and other conditions, or have not necessitated any action until the present time. Replacement of the aluminum diffuser plate holders in the aeration tanks is probably the most critical problem in this regard.

Comminutors and Detritors

The four 54-in. comminutors were operated a total of 16,708 machine hours, as compared to 17,377 machine hours during 1946. The original No. 1 comminutor was replaced by a new unit, put into operation May 15. Changes in the design of the new comminutor have greatly increased its rigidity, with improved operation resulting. Wear resulting from the passage of grit through the comminutors is still a problem with the new machine, as it has been with the older ones, and reconditioning of the cutting elements, such as teeth, shear bars, and combs, continues to be an important and large item of plant maintenance work. During the year 1,514 teeth, 25 combs, and 227 shear bars were reconditioned and fabricated in the plant machine shop. The No. 2 comminutor must be replaced as soon as possible, and the remaining two in a matter of 2 or 3 more years. A new drum was installed on one of the 36-in. comminutors and a new drum has been procured and will be installed on the other 36-in. comminutor.

Bar Screens and Grit Chambers

Cleaning of the grit chambers continues to cause a periodic odor nuisance. It has been recommended that grit washing be considered as the means of preventing this nuisance.

The main sluice gate controlling the sewage flow to the 6 west grit chambers was equipped early in the year with a hand-operated, geared stand mechanism, replacing the hydraulic cylinder. A portable motorized unit was fabricated to operate the stand mechanism, and suitable limit switches were also installed. A contract has been effected for the additional number of stands needed to replace all of the hydraulic cylinders in the screen building. When this work is concluded, it will be possible to control properly sewage flows in the individual grit chambers.

Southerly Sludge Pumps and Force Main

A total of 210 m.g. of sludge, containing 3.8 per cent of dry solids, was pumped 13 miles through the 12-in. force main to the Southerly plant for final disposal. Based on the analysis of samples taken at the Southerly end of the force main, 65,368,000 lb. of dry solids were transported in the sludge. The sludge pumped was the most concentrated ever delivered and compares to 3.5 per cent dry solids in 1946, and 3.3 per cent in 1945.

The sludge force main was again only in operation on a part time basis, due to the fact that the volume pumped did not require full time operation. The sludge pumped for the main part consisted of a mixture of waste activated and primary sludge removed from the primary tanks, although some concentrated waste activated sludge was also pumped for the purpose of establishing pumping rates, and infrequently, to reduce the sludge line friction resistance. The average pumping rate was 1.19 m.g.d. at 156 p.s.i. and 159 amperes.

The force main was partially cleaned June 24–26. Stoppage of the cleaner made it necessary to employ the por-

table high pressure pumping unit to move the cleaner from its stuck location to a point where a pipe section had been removed from the sludge line. On July 15, the sludge line was cleaned throughout its entire length without any difficulties, and in the record time of 7 hours and 25 minutes. On October 14–15 the entire sludge line was again cleaned, but the cleaner became stuck and it took 4 or 5 hours before pressure applied by the Southerly pumps was able to start the cleaner going again. Further difficulties occurred at the Southerly end of the sludge line when the cleaner "hung up" for some time in a partially opened valve in the junction box.

The installation of a raw sludge meter is being considered. Continuous metering facilities would improve the sludge pumping operation by furnishing pumping rates at all times, and eliminating the awkward method by which these pumping rates are now obtained.

Aeration Tanks and Blowers

An average air consumption of 0.72 cu. ft. per gal. of sewage was achieved, which is the lowest ever attained for the plant. The mixed liquor from the aerators averaged 1,780 p.p.m. suspended solids and had an average sludge index of 93. The return activated sludge averaged 6,270 p.p.m. suspended solids and was returned at 26.3 per cent of the settled sewage flow. The settled sewage D.O. averaged 1.4 p.p.m., with the final clarifier effluent averaging 2.9 p.p.m.

Considerable experimental and development work was done in connection with a replacement program for

TABLE I.—Summary of 1947 Operating Data, Easterly Plant, Cleveland, Ohio

Item	Average
Raw sewage flow (m.g.d.)	104.0
Settled sewage flow (m.g.d.)	99.5
Grit removed (cu. ft. per m.g.)	4.47
Screenings removed (cu. ft. per m.g.)	0.29
Suspended solids (p.p.m.):	
Raw	246
Settled	201
Effluent	13
Per cent removed	95
B.O.D. (p.p.m.):	
Raw	192
Settled	126
Effluent	9
Per cent removed	96
Oxygen consumed (p.p.m.):	
Raw	96
Settled	78
Effluent	20
Per cent reduction	79
Dissolved oxygen (p.p.m.):	
Raw	1.4
Aerator influent	1.4
Aerator effluent	2.9
Final effluent	3.9
Ammonia (p.p.m.):	
Raw	10.4
Settled	7.5
Effluent	6.0
Nitrite, effluent (p.p.m.)	0.5
Nitrate, effluent (p.p.m.)	2.3
Sludge pumped to Southerly plant (m.g.)	209.7
Per cent moisture, average	96.2
Activated sludge (average):	
Total solids (p.p.m.)	6,270
Volatile solids (%)	62
Mixed liquor suspended solids (p.p.m.)	1,780
Sludge index (ml./gram)	93
Postchlorination:	
Days applied	91
Application rate (p.p.m.)	4.4
Residual maintained (p.p.m.)	0.7
Bacterial count; agar plates at 37½° C. (1,000 per ml.):	
Raw	2,850
Effluent	170
Chlorinated effluent	18
Per cent reduction	99.35
Presumptive B. coli (1,000 per ml.):	
Raw	113.1
Effluent	2.08
Chlorinated effluent	0.06
Per cent reduction	99.89
Plant costs ($ per m.g.):	
Operation and maintenance	14.79
Administration	2.52
Total	17.31

the aluminum diffuser plate holders. A welded, steel-frame diffuser plate holder was devised that can be grouted into available concrete channels in the bottom of the aeration tanks. The design is such that practically no air piping changes are necessary. The diffuser plates are attached to the frames in exactly the same manner, using similar fittings and gaskets to those used in connection with the aluminum plate holders. The metal surface of the frame exposed to the sewage is very small. Stainless steel washers, angle clips, and cap screws replace the aluminum fittings formerly used. The aluminum diffuser plate holders were removed from No. 3 aeration tank and 134 steel frames, which were fabricated in the plant machine shop, were installed. Several recommended paints were used to protect the metal frames, and it is hoped that information of real value will become available in this connection in the course of time. No. 3 tank was put back into service November 1.

Early in the year a system of permanent log books was introduced in the various operating units. The purpose of these logs is to segregate and accumulate the permanent routine operating instructions, so that these are always available for immediate reference. It is hoped that the permanent log books will develop into "Operating Manuals," will result in more efficient operation, and will definitely fix responsibility for the performance of various tasks and duties.

Operation data for 1947 are summarized in Table I.

Report on the Operation and Maintenance of the Westerly Sewage Treatment Plant, Cleveland, Ohio, for the Year 1947 *

By John O. Barrett, *Assistant Superintendent*

Excessive rainfall in the early months of the year delayed the cleaning of Imhoff tank gas vents until early summer. The gas vents were washed and the scum added to the digesters as was customary; but, due to the great amounts added to the digesters in a relatively short time, the scum layer depths increased in the digesters to a point which would have impaired the operation of the digesters during the winter season. For this reason and the fact that a large quantity of grit had accumulated, all six digesters were pumped down and cleaned out. The scum was pumped to the plant influent.

Sewage Flow, Screenings, and Grit

The total sewage flow of 12,034.6 m.g. was the greatest ever recorded at the Westerly plant, with the average monthly flow of 1945 being surpassed during 11 months of the year. The recorded flow includes 15.0 m.g. of supernatant liquor returned to the plant influent from the digesters. An average daily flow of 33.0 m.g. was handled. The storm water overflow operated an average of 19.9 hr. per month, or 2.73 per cent of the total time.

Grease Aeration

The aeration tanks, which have been out of service for several years, were placed in service the latter part of the year. Perforated pipes were installed in one-half of each tank, instead of Filtros plates. The object was to provide additional channel distance between the grit chambers and the Imhoff influent channels, in an attempt to arrest the passage of grit to the sedimentation tanks. Only a small quanity of air was used to prevent the

* For previous extracts see This Journal, **12**, 3, 625 (May, 1940); **15**, 1, 99 (Jan., 1943); **18**, 1, 113 (Jan., 1946); **20**, 3, 551 (May, 1948).

organic material from depositing with the grit.

Sedimentation

Both 8-in. cone valve hydraulic control assemblies in the north gallery were overhauled. The brass cylinders were reversed and new cup leathers were installed on the pistons. A solenoid coil on the pilot control valve actuating the hydraulic mechanism of one of the valves was replaced.

During the early part of the year, severe weather conditions prevented the poking of the Imhoff tank slots. As a result, the slots of several tanks became blocked. It was necessary to pump down these tanks and clean the slots by a stream of high-pressure water.

Numerous repairs were made to the gas vent covers, several being replaced by new covers fabricated from soft pine and creosoted. Cypress lumber, much more desirable from a durability standpoint, was not available.

Digester Heating

Repeated failures of sections in the No. 5 digester heater made it necesary to replace the entire coil section. During the year leaks developed in coils of two other heaters, but only the broken sections were replaced. The balance of the heating units will require complete new coil sections in the near future. Failure of the heater sections is due to corrosion on the outer surface of the coils and is undoubtedly the result of excessive moisture in the gas and the probable conversion of hydrogen sulfide gas to sulfuric acid.

Sludge Vacuum Filtration

The galvanized iron wire screens purchased during the war period for the vacuum filters are badly deteriorated and require replacement. The monel wire screens on the one original filter are in excellent condition, after approximately 10 years of service, whereas the other three filters have had one set of copper screens and one set of galvanized iron screens. This experience indicates that monel wire screens are more economical in the long run; therefore, an order has been placed for screens of this noncorrosive metal alloy.

The use of monel wire has been adopted for wrapping the vacuum filters after a test proved its practicability.

A new crankshaft for the No. 3 vacuum pump was obtained with oversize ends and the flywheels were bored to fit the new shaft size. This pump was out of service several months, due to delay in delivery of the new part.

The inside piping of No. 1 and No. 3 vacuum filters was replaced by new heavy red brass pipe, and minor changes were made in the position of the vacuum nozzles to give more even distribution of the vacuum.

Due to difficulty in procuring pebble lime for some time, it was necessary to change the chemical dosing of the digested sludge preparatory to filtration. Lime dosages were cut to a minimum and ferric chloride dosages were increased, but no combination was found which proved as satisfactory as the normal procedure.

Incineration

When sludge and scum mixtures or a sludge cake with high volatile solids content is being incinerated the load is divided, if possible, between the two incinerators even though the total load is not above the capacity of one incinerator under normal conditions. It has been proven that temperatures can thus be more easily controlled and kept below the critical temperature recommended for the rabble arms.

The amount of trouble experienced in the ash slurry equipment and the discharge line was below normal, but blockage due to clinkers in the ash hoppers and fly ash throughout the incineration building showed a noticeable increase.

Miscellaneous Maintenance

Snow fencing was purchased and erected. This fence proved to be an asset, serving to reduce the labor required in keeping the driveway clear of snowdrifts.

Two new type 15-lb. CO_2 fire extinguishers were placed in the incineration building, which contains the greatest number of electric motors.

Table II is a summary of operation data for 1947.

TABLE II.—Summary of 1947 Operating Data, Westerly Plant, Cleveland, Ohio

Item	Average
Raw sewage flow (m.g.)	33.0
Grit removed (cu. ft. per m.g.)	3.86
Per cent volatile	23.0
Suspended solids (p.p.m.):	
Raw	262
Imhoff tank effluent	179
Per cent removed	31.1
B.O.D. (p.p.m.):	
Raw	260
Imhoff tank effluent	210
Per cent removed	19.4
Oxygen consumed (p.p.m.):	
Raw	182
Imhoff tank effluent	164
Per cent reduction	10.0
Total bacteria (1,000 per ml.):	
Raw	1,568
Imhoff tank effluent	741
Presumptive B. coli (1,000 per ml.):	
Raw	196
Imhoff tank effluent	86.10
Prechlorination:	
Days operated	87.0
Average dose (p.p.m.)	8.71
Postchlorination:	
Days operated	69.8
Average dosage (p.p.m.)	6.10
Average residual (p.p.m.)	2.12
Raw sludge to digesters:	
Number of additions per month	77
Temperature (°F.)	57
Volatile solids (%)	61
Total solids (%)	65.0
pH	6.5
Alkalinity as $CaCO_3$ (p.p.m.)	930
Digester supernatant:	
Total solids (%)	0.79
Volatile solids (%)	50.5
pH	7.9
Alkalinity, as $CaCO_3$ (p.p.m.)	2,480
Sludge storage tank supernatant:	
Total solids (%)	1.3
Volatile solids (%)	51.0
pH	7.8
Alkalinity, as $CaCO_3$ (p.p.m.)	2,660

Item	Average
Gas production:	
Daily production (cu. ft.)	196,000
Cu. ft. per lb. volatile solids	8.3
CO_2 (%)	31.4
Utilization of digester gas:	
Digester heaters (%)	26.5
Building heaters (%)	18.2
Incinerators (%)	21.0
Wasted (%)	34.3
Digested sludge vacuum filtered:	
Total solids (lb. per month)	463,700
Total solids (%)	7.79
Volatile solids (%)	50.6
pH	7.8
Alkalinity, as $CaCO_3$ (p.p.m.)	2,680
Chemical dosage for vacuum filtration (%):	
Ferric chloride	3.39
Lime	12.2
Calcium oxide	11.0
Sludge filtration:	
Filter cake:	
Moisture (%)	67.1
Volatile solids (%)	44.6
Pounds dry solids per sq. ft. filter area per hr.	2.95
Filter cake per filter hour (tons)	0.74
Average filter cloth operating life (hr.)	198
Filtrate (p.p.m.):	
Total solids	3,808
Suspended solids	353
Alkalinity, as $CaCO_3$	1,920
Sludge filter cake incineration:	
Tons per month incinerated	587
Tons per incinerator hour	1.32
Tons used for soil conditioner	2,547
Fuel oil used:	
Gal. per ton of filter cake	0.150
Gal. per ton of dry solids	0.453
Gas used:	
Cu. ft. per ton of filter cake	704
Cu. ft. per ton of dry solids	2,123
Plant costs ($ per m.g.):	
Operation and maintenance	12.69
Administration	2.51
Total	15.20

Report on the Operation and Maintenance of the Southerly Sewage Treatment Works, Cleveland, Ohio, for the Year 1947 *

By G. E. Flower, *Superintendent*

During the year, the Southerly sewage plant treated a total of 14,477.5 m.g. of sewage, which was 1,185.8 m.g. more than in 1946. Part of this increase came from an increase of 16.02 in. of rainfall over that of 1946, and also from more supernatant liquor from the concentration tanks. The above flow contained 4,339,800 gal. of concentration tank supernatant liquor.

The abbreviated aeration units treated 6,839.3 m.g. of Imhoff tank effluent, or 47.2 per cent of the entire flow.

Abbreviated Aeration Unit

These units removed 52 per cent of suspended matter and 66 per cent of B.O.D., using 0.53 cu. ft. of air per gal. of settled sewage. This means that 1,320 cu. ft. of applied air were used to remove 1 lb. of B.O.D.

Trickling Filters

The trickling filters treated 7,889 m.g. of Imhoff tank and aeration unit effluents, which amounted to a loading of 5.25 lb. B.O.D. per 1,000 cu. ft. filter media in 24 hours.

The trickling filters are still pooling badly and are not showing any indication of clearing.

Sludge Drying Beds

The drying beds partially dewatered 2,234,200 gal. of Imhoff tank sludge, averaging 8.7 per cent solids, or 20 per cent of all the sludge removed from the Imhoff tanks. The moisture of the sludge was reduced to an average of 62.7 per cent.

Concentration Tanks

The concentration tanks were used as a receiving well without any concentration during the entire year for the Easterly plant sludge and only up to July for the Southerly plant excess activated sludge from the abbreviated aeration tanks.

Starting in July, the Southerly plant excess activated sludge was pumped to one concentration tank and allowed to settle. The clear supernatant liquor was then pumped to the raw sewage and the concentrated solids to the separate digestion tanks. The sludge was concentrated from 2.54 per cent solids to 4.06 per cent solids.

Vacuum Filtration

Average costs of chemicals for the last year were as follows:

Ferric chloride, per ton	$47.50
Lime, per ton	11.90
Lime, per ton dry solids	1.39
Ferric chloride, per ton dry solids	2.77

Dry solids content of the filter cake averaged 28.9 per cent. The average filter cloth life was 347 hr., compared to 287 hr. in 1946.

The total amount of filter cake produced was 52,780.9 tons, which was 14,007.2 tons less than in 1946. There was 242.6 tons of filter cake given away as a soil conditioner; the balance was incinerated.

Difficulty in maintaining a proper schedule of lime shipments caused a shut-down of the vacuum filters and incinerators at various times. This was due to shortages of cars and coal at the source of supply. A larger storage capacity for the lime would help to eliminate this trouble. There was no difficulty in maintaining an ample supply of ferric chloride.

* For previous extracts see This Journal, **12**, 3, 625 (May, 1940); **15**, 1, 99 (Jan., 1943); **18**, 1, 113 (Jan., 1943); **20**, 3, 551 (May, 1948).

TABLE III.—Summary of 1947 Operating Data, Southerly Plant, Cleveland, Ohio

Item	Average
Rainfall (in.)	43.99
Raw sewage flow (m.g.d.)	39.7
Screenings removed (cu. ft. per m.g.)	0.53
Grit removed (cu. ft. per m.g.)	1.92
Per cent volatile	39.6
Abbreviated aeration unit:	
Flow (m.g.d.)	19.0
Per cent of total flow	47.2
Air used (cu. ft. per gal.)	0.53
Trickling filters:	
Flow (m.g.d.)	21.9
Per cent of total flow	55.2
Suspended solids (p.p.m.):	
Raw	194
Imhoff tank effluent	100
Dorr tank effluent	48
Filter influent	98
Filter effluent*	69
Final effluent**	322
Dissolved oxygen (p.p.m.):	
Raw sewage	5.8
Imhoff tank effluent	3.0
Dorr tank effluent	1.7
Filter effluent	5.0
Plant effluent*	5.0
River above plant	9.9
River below plant	8.8
B.O.D. (p.p.m.):	
Raw	138
Imhoff tank effluent	73
Dorr tank effluent	25
Trickling filter influent	66
Plant effluent*	41
Final effluent**	92
River above plant	6
River below plant	17
Oxygen consumed (p.p.m.):	
Raw sewage	84
Plant effluent	44
Final effluent**	100
Nitrogen—raw sewage (p.p.m.):	
Free ammonia	27
Organic N, total	19
Nitrogen—plant effluent (p.p.m.):	
Free ammonia	21
Organic N, total	12
Sulfates in raw sewage (p.p.m.)	201
Imhoff tank sludge:	
Total solids (%)	8.7
Volatile solids (%)	48.9
Sludge drying beds:	
Per cent Imhoff tank sludge dried	20
Moisture content dried sludge (%)	62.7
Digester operation:	
Raw sludge:	
Volume (m.g.)	229.2
Per cent from Easterly plant	93
Per cent from Southerly plant	7
Dry solids (mil. lb.)	70.4
Volatile solids (mil. lb.)	44.8
Digested sludge:	
Volume (m.g.)	29.2
Dry solids (mil. lb.)	17.3
Volatile solids (mil. lb.)	8.3
Total solids (%)	7.04
Volatile solids (%)	47.7
Alkalinity (p.p.m.)	2,880
pH	7.4
Supernatant:	
Volume (m.g.)	198.9
Total solids (p.p.m.)	19,591
Volatile solids (p.p.m.)	10,142
Suspended solids (p.p.m.)	17,866
Gas production:	
Volume (1,000 cu. ft. per day)	803.9
Cu. ft. per lb. vol. solids	6.7
Per cent CO_2 in gas	31.1
B.t.u. (net)	602
Gas utilization (per cent):	
Wasted	43.0
Digester heating	29.9
Incinerators	6.4
Gas engines	14.3
Building heat and miscel.	6.4
Vacuum filtration of sludge:	
M.g. filtered	38.0
Mil. lb. dry solids	23.1
Chemicals used (%):	
Ferric chloride	5.79
Lime	11.77
CaO	10.45
Filter cake production:	
Tons dry solids	1,277.4
Per cent solids	28.9
Filter rate (lb. dry solids per hour per sq. ft. filter area)	3.06
Filter cloth life (hours)	347
Filtrate (p.p.m.):	
Total solids	6,266
Susp. solids	457
Alkalinity	1,753
Sludge incineration:	
Sludge cake (tons)	52,538
Sludge cake (tons per incinerator hour)	3.48
Ave. B.t.u. per lb. vol. solids	11,898
Filter cake moisture (%)	71.1
Filter cake per cent volatile	43.8
Plant costs ($ per m.g.):	
Operation and maintenance	13.17
Administration	2.54
Total	15.71

* First 6 months, trickling effluent only. Last 6 months, trickling filter and Dorr tank effluents combined.

** Contains trickling filter and Dorr tank effluents, digester supernatant, vacuum filter filtrate, and plant overflow.

Incineration

Filter cake was incinerated at a rate of 3.5 tons per hr. for a total of 627.6 incineration days, or an average of 84.0 tons per 24 hr., the same rate as obtained in 1946. More new alloy-steel rabble arms and rabble teeth were installed and are giving excellent service.

Operating data for 1947 are summarized in Table III.

DIGITALIS AND SPLINTS FOR TWO DIGESTERS *

By I. O. Lacy

Superintendent, Sewage Treatment Plant, Lockport, N. Y.

The geologic history of the Lockport, N. Y., sewage treatment plant site is responsible, in the main, for the title of this paper. The various structures of the plant are underlain by approximately 80 ft. of clay, and no piling was provided in the foundations. In view of these conditions, the effects of which are explained subsequently, and the fact that the plant must continue in operation, policy has been simply to "try to keep it going; maybe it won't fall apart."

This discussion deals with the plant's two digesters and the operating and maintenance problems involved. Both units are brick-veneered and glass wool insulated, are fitted with fixed covers and Hardinge mechanism, and are heated by circulating hot water. Each is 55 ft. in diameter and 21 ft. deep, providing a combined capacity of 101,600 cu. ft., or about 4 cu. ft. per capita for the city's 25,000 population.

It was planned that these units would receive and digest all the solids and scum from the settling tanks when they were put in operation in November, 1940. It was found, however, that about 200 g.p.d. of used lubricating oil were being received from a copper rolling mill. Immediately the units were full of oil and sludge. Before anything could be done about it, the shear pins of the driving mechanism broke. This was on Dec. 16, 1940. New pins gave no relief. It was decided to empty the west digester, and continue operation with only the east unit, because the supernatant from this tank flows by gravity to the influent well. The sludge was pumped to a lagoon on the plant grounds. As soon as the weather permitted a lagoon was constructed to handle the oil. The collected grease and oil then and now are periodically burned.

Effects of Subsidence

Inside the west digester in May, 1941, it was found that the foundation for the mechanism had separated from the floor, the floor itself having risen some in the middle circumference. The mechanism rested on the floor in several places. As the take-up bars were tightened to the limit and it was felt that the clearance was not sufficient in some places, several 6-in. deep rakes were cut to 3-in. and replaced. The mechanism foundation joint was caulked with lead wool.

The unit was back in operation Oct. 2, 1941, but it was only a month before the shear pins broke again. Elevations showed that the walls were settling, and that the floors were tending to buckle some. The digester control house, between the digesters, seemed to act like the binding of a book, the covers of which (the two tanks), while fastened at one place, were settling on the outside edge. In fact, this settlement was as much as 1.09 ft. The two sludge entrance pipes are about 5 ft.

* Presented at 33rd Annual Meeting, New Jersey Sewage Works Association; Trenton, N. J.; March 10–12, 1948.

apart vertically, and to date have shown no leaking at the point of entry. As a precautionary measure expansion joints were installed in the gas collection lines.

Rather than a detailed description of the times each tank has been entered, a more casual account will be presented. Once, after a power failure, the mechanism refused to run and it was found that the seventh set of taper pins was broken. Therefore, the size of the shear pins was increased to $\frac{3}{8}$-in. bolts. Several times the mechanism just stopped because the rakes were scraping on the uneven floor. The remedy was simply to raise them. Once, the small sprocket on the worm was frozen. Its release and subsequent pin replacement gave no relief.

Dumping of the sludge could not always be accomplished when desired. With only one operator on a shift, only so much could be done. The plant is equipped for vacuum dewatering, but experimental filtration showed high costs, the budget showed little money, and there was lagoon space, plus 10,000 sq. ft. of open drying beds. This lagoon space was a grand thing to have. The sludge drawn sometimes was not digested, but on only one occasion were there any odor complaints.

The sludge scrapers are so designed as to cause a section of undisturbed sludge (outside depth 18 in., inside depth 4 to 5 in.) to be formed on the bottom. The manufacturer wondered if cutting the depths of some scrapers had been the right procedure. Therefore, the pieces were welded back on, shims were placed under the center fastening, the scrapers were raised, the new tie rods were tightened, and the unit was ready to be placed back in service. This time sludge that was not doing much of anything in the east tank was transferred. Maybe the bugs needed a change of environment—at any rate some lime was added, just for luck.

In a few days the west digester was bubbling all over the place. For about a week, small batches of sludge were transferred to the other digester, which was almost empty. The pH was right, the temperature was fair, and it is presumed that the trouble was caused by the entire accumulation starting to digest at once. At any rate, the foaming stopped, the gas lines and meter were cleaned, the rakes were running, and attention could be turned to other jobs. All went well for a long time, until the operators said that once in a while there was a noise from inside the tank. Then a taper pin broke. After this was repaired all seemed to be going fine.

Soon after the plant was put in operation the movement of the structures had sheared off the sludge line to the drying beds. In making the repair a tee had been placed in the line, extended to about 3 ft. above ground, and blank flanged. Therefore, when sludge was seen coming up from the other side of the building another messy job was anticipated. However, this turned out to be only a loose joint in the supernatant line to the influent well. Because the sewage level was at a greater elevation, the sewage just flowed to where it was not expected or wanted.

Scum Breaker Damage

The east digester was now cleaned, a long, slow, messy job with attendant pump troubles. Tomato seeds presented a major problem. The scum breaker arms were found to be wrapped around the torque tube like ribbon, but still fastened to some extent at the top. One short strengthening arm had one bolt left and was badly bent; the other arm was off, and the bolts were gone. Most of the missing bolts had been picked out of the pump. As the scum breaker arm is designed to take a maximum horizontal stress only one third that for the sludge scrapers, the constant push had probably caused the damage.

Repair of the machine was not easy. Originally, the scum breaker arm was put in place before the roof was poured. Now, a 25-ft. long piece of 4 by 4 by ¼ steel angle with 30-in. teeth had to be put through a 2-ft. by 3-ft. manhole, the bottom of which was 17 ft. from the floor. The piece weighed about 450 lb. The arm was cut in half, and 2½ in. was cut from each tooth. The pieces were then manoeuvered into the tank. Inside, the two pieces were welded together, ready for raising to position. This turned out to be quite a task; in fact, the longest and hardest part of the job. The arm goes rather close to the ceiling, so it could not be raised by fastening to the teeth. However, a rope was dropped through the torque tube opening, and another through the manhole. The arm was then raised, and two men standing on a 14-ft. high, heavily built scaffold tried to get the teeth upright. That done, the two bolt holes had to be matched up and the arm held in position long enough for the brackets to be welded in place.

A 5-ft. length of 2-in. pipe was welded to the outside end of the second arm. At each end of this pipe a sheave was fastened, with a third sheave on the other end of the arm. Ropes through the sheaves and up through the roof were used to raise the assembly. It was almost in place when it turned over. Finally, after much exertion, it was in place and welded. The welder, a former oil field man, really was the fellow who guided the job. The east tank was back in operation Dec. 1, 1947.

Remember the bumping noise in the other digester? As sludge was transferred to start the east tank again, the scum rakes did not go by the manhole, although the wormgear was turning. The inspection hole cover was removed, a safety light was dropped, and the scum breaker arms were found to be riding on the sludge scrapers. If necessary to fix this machine with plant personnel a different method will be used to raise the arms to position.

As for the solids load doing the damage, it does not seem possible that this could be the trouble in itself. There are four sampling elevations—1½, 7, 12½, and 18 ft. off the floor. It has always been possible to sample by gravity flow, even without backwashing. However, the scum arms seem to be broken off at the torque tube and it is likely that they can be used again, because they do not appear to have been bent badly.

Some sludge was found on the heating pipe coils, but no real caking. The inlet water is usually about 120° F.; the outlet water, 90° F. In the torque tube opening, sludge was packed rather tightly. No practical method of breaking this up has been found.

PORTABLE SAND PUMPING RIG

By B. Benas

Superintendent, Richmond-Sunset Sewage Treatment Plant, San Francisco, Calif.

Practically every sewage treatment plant has the problem of removing deposited material from channels, sumps, and tanks. The portable pumping rig shown in Figure 1 was designed by Ralph R. Sotter, chief operating engineer of the Richmond-Sunset sewage treatment plant, to perform just such service without dewatering the unit involved.

The entire rig is mounted on a flat bed, rubber tired, industrial type dolly for ease in moving from point to point as required. The pump, a 4-in. centrifugal sand and sludge pump with a hardened semi-open impeller and side

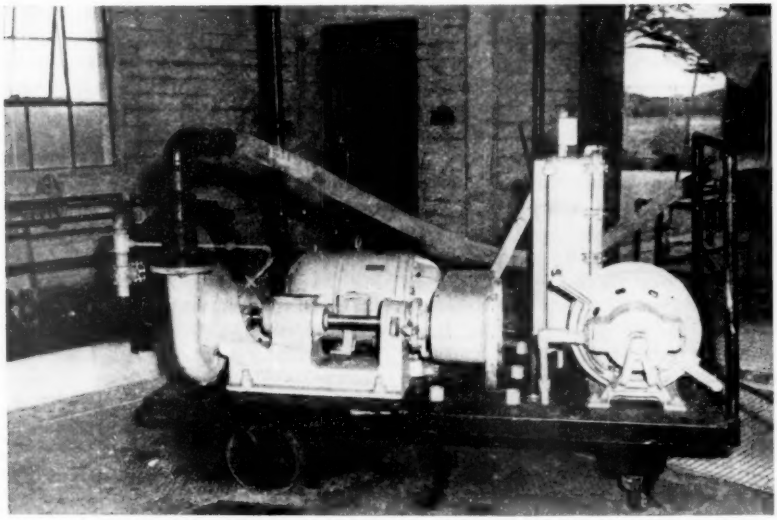

FIGURE 1.—Portable pumping rig for removing deposited material without dewatering plant units.

plate, is driven by a 15-hp. motor and has a capacity of 250 g.p.m. against a total dynamic head of 125 ft. Power control equipment mounted on the dolly includes the starter switch, cut-out switch, and overload protection, as well as 50 ft. of flexible power cable. Plug outlets have been installed at convenient locations throughout the plant for use of the pump. A 1½-in. water connection is provided on the suction side of the pump for priming.

In operation, the 2½-in. suction hose is moved along the bottom and the pumped material is discharged through a 3-in. flexible or canvas hose to the channel ahead of the grit chambers. The portable pumping rig has been in service about one year and has proved to be of inestimable value in saving time and labor by allowing plant units to be kept clean without shutdown. No maintenance has been required, other than normal greasing and oiling.

PROTECTIVE PAINTS AND COATINGS FOR SEWAGE TREATMENT PLANTS*

By Frederick V. Kroeber

Inertol Company, Inc., Chicago, Illinois

The continuous operation and the structural life of sewage plant facilities are essential considerations of every plant superintendent. In his annual budget the superintendent will generally set aside funds for those essential items required for good plant maintenance, such as protective paint coatings.

* Presented at the 1948 Annual Meeting of the Indiana Sewage Works Association, December 4, 1947; reprinted from *Sewage Gas*, Sanitary Engineering Division, Indiana State Board of Health.

Paint failures disrupt organized plant routine, usually requiring withdrawal of essential units from service for the purpose of repainting surfaces and also requiring the re-assignment of plant personnel from other important work, to painting. Only the largest sewage plants find themselves in a position to sub-contract the labor of painting.

Painting in sewage treatment plants serves only the reasons of protectiveness, cleanliness, and attractiveness. Measured in economic costs painting frequently strikes the happy average of two-thirds of its cost in labor, one-third of the cost in materials utilized, applied.

Thus it can be easily seen that it is a fallacy to purchase a product which offers, for instance, one year's service, when another product available at the same time might offer a 3-yr. performance. It is false economy to utilize inferior paints deficient in lasting qualities. It is always good policy to buy the best the market offers for sewage plant painting, thus insuring, once applied, that all conditions to which a surface is subjected are met.

It has been said that when you buy paint you buy a promise in a can. Frankly, this is a somewhat gloomy picture and is not entirely supported by facts. There are available on the paint market highly suitable products that will afford protection, beauty, or cleanliness to every type of sewage treatment plant surface, whether of iron, steel, plaster, brick, or concrete. Products may be especially designed to waterproof surfaces, insure chemical resistance, or withstand moisture, condensation, and heat—yes, even fire. Many of these are new formulations that came into acceptance when World War II accelerated the need for more effective weapons to combat the corrosion of metal surfaces and the disintegration of concrete, brick, and plaster.

In the past, consulting engineers, in the process of sewage plant design, have erred somewhat in not fully protecting surfaces of concrete, brick, and plaster against moisture absorption and moisture penetration, and in not providing surface coatings which promote good housekeeping, probably being minded at the time to direct all their attentions to the processes of treatment, velocities of flow, detention times, and other such matters. Leaving the surfaces vulnerable to acid attack, weathering, and other deteriorating processes once a plant has been placed in operation, is somewhat analogous to leaving a 2-day old infant to its fate in the world.

The opinion is ventured that there is hardly a plant in the Central States area which does not now have or has not had some trouble due to surface spalling, capillary action, and other conditions that could readily have been prevented if a wider utilization of protective coatings had been made at the proper time.

This paper is confined to the description of the types of surfaces found in sewage treatment plants on which specialized products will give better service, will make housekeeping operations easier, and will provide better protection and longer performance. Not covered is the application of ordinary paints and enamels of drying oil base, or cement base types, which undoubtedly can be used successfully on ordinary surfaces.

Aeration Tanks and Primary Settling Tanks

Domestic sewage contains greases and oils that rise to the top, at sewage level, and deposit on the side walls of aeration tanks and settling tanks, often setting up rancid conditions when they get old, thus causing odors in the neighborhood. As an aid in good housekeeping operation it is recommended that such tanks receive a 2-coat application of a thoroughly waterproof, chemical resistant, black

coal tar pitch enamel, which when applied will furnish a smooth, glossy black finish to these walls. This coat is usually applied 1 or 1½ ft. above sewage level and to a depth at the discretion of the superintendent or consulting engineer.

Coal tar pitch enamel, in the presence of large amounts of grease and oil, may in time have a tendency to soften. Therefore, in plants carrying meat cutting, dairy, and other highly greasy wastes a vinylite resin base product should be substituted.

Pipelines Above and Below Ground Level

Recently, a consulting engineer connected with the Los Angeles (Calif.) Water Department concluded that no better product can be used for pipelines, above or below ground level, than a thoroughly refined, chemical resistant, waterproof coal tar pitch enamel. The writer concurs in this opinion. Inasmuch as color is unessential in pipelines, except those which are to be identified by color, it is recommended that pipelines above ground level be given a 2-coat application over a high grade red lead-zinc chromate primer, allowing 24 hr. drying time between coats. For buried pipe, a 3-coat application, without primer, will prove satisfactory, although pitted and rusted pipe should be treated first with a penetrating oil, slow oxidizing type primer (such as a rust sealer), which will carry the rust inhibiting agent into ragged pits and pores. Painting should begin not sooner than 6 to 8 days after application, allowing sufficient time for the rust sealer to oxidize.

Pipelines that are to be identified in color will darken in the presence of hydrogen sulfide gas if ordinary oil base paints and enamels are utilized. In such a case, a vinylite or bakelite base product that will remain colorfast and unaffected by hydrogen sulfide gas is recommended. It should be remembered, however, that most synthetic paints are easily discolored by a "bleeding through" action when placed over a product containing tar, pitch, or asphalt, and if a product has been utilized to prevent condensation or sweating of pipelines, this should first be sealed off with a heavily pigmented aluminum base product compatible with the synthetic type coating so that a blistering action will not result. The highly active solvents contained in synthetic type paints often react on a previously painted surface, but a small patch application will readily determine if such action will take place, as the blistering action will occur within a minute or so after application, if at all.

Clarifier Mechanisms

As most sewage plant superintendents are well aware, the greatest destructive action, other than abrasion, occurs in clarifier mechanisms when such equipment is out of service. The painting of such equipment, therefore, entails a somewhat more complex procedure than ordinary applications.

Assuming that a clean bright metal surface has been obtained by wire brushing and scraping, or by sand blasting (where the prime coat is evident, just those surfaces which have been abraded), it is recommended that these bare metal surfaces be first "passivated" with a chemical inhibiting wash containing phosphoric acid. This procedure is rapidly becoming accepted practice for painting metal surfaces submerged below water or sewage level.

The phosphoric acid treatment of metal surfaces came into practice about 15 years ago and has been widely used since. The prime objective of the procedure is to convert the metal surface into a non-metallic phosphate film, which isolates the metal from the primer applied later; slightly etches the metal, thereby giving better adhesion to the primer; and inhibits the

further spread of corrosion should the primer become abraded at a later time. Phosphoric acid is not harmful to the skin and is easily neutralized by soap and water. Nevertheless, in applying it care should be exercised to avoid splashing the material on clothes, and workmen should be protected with goggles and gloves. After the surfaces have dried this treatment should be followed by a 1-coat application of a high grade red lead-zinc chromate rust inhibitive primer and 2 coats of a highly refined coal tar pitch enamel product that incorporates a plasticizer for flexibility in the coating.

When color is desired on metal surfaces above sewage level, including the walkways, full protection may be afforded by the application of primer and 2 coats of phenol-formaldehyde bakelite base product, which is thoroughly waterproof, chemical resistant, and smooth and tile-like in appearance, and will be found to resist dirt and greases and to be unaffected by hydrogen sulfide.

The mistake should not be made of using ordinary aluminum paint for such applications. There are just as many types of aluminum paints available as there are vehicles in which 2 pounds per gallon of vehicle (the standard content of aluminum flake in vehicle) can be manufactured. For this type application, a specialized waterproof vehicle is an essential consideration.

Digesters

The inside waterproofing of digesters warrants consideration from both the operating and protection standpoints. A thoroughly refined coal tar pitch enamel coating, applied on the sidewall surfaces, will render the structure watertight and gasproof. It may also inhibit structural damage by freezing and thawing, because sludge, like water, has a tendency to leach out the soluble lime in concrete, thus making possible moisture absorption as the surface becomes porous. The smooth, tile-like finish of the coal tar enamel will encourage sludge to slip from the side walls and not cake.

Floating covers of digesters are best protected inside and out by the use of a high-grade red lead-zinc chromate rust inhibitive primer, followed by two coats of a heavy bituminous paint incorporating a plasticizer for flexibility of coating. If color is desired, the exterior surfaces of the gas dome, the upper inside of the rim, the topside of the ceiling, and the trusses and purlins may be finished off with a chlorinated rubber base product in color as selected.

Miscellaneous Metal Surfaces

Perhaps no group of synthetic resins has come more to the fore in recent years than the alkyd resins. These were used during the war with outstanding success on all types of vehicles and structures, and for painting ships above the water line.

The resins used in the manufacture of alkyd enamels are a combination of many types of polybasic acids, polyhydric alcohol, and unsaturated fatty acids; an almost unlimited number of possible combinations may be produced. Enamels of this type dry overnight and display unusual color retention and gloss, even after prolonged outside exposure. They effectively resist temperatures up to 400° F., as well as gasoline, lubricants, and oil, and provide excellent porcelain-like finishes for metal trim and machinery.

Buildings

Wall and ceiling surfaces of brick, plaster, or concrete in sewage plants are subjected to dampness and moisture, and, at times, to condensation and hydrogen sulphide gas. To insure a lasting paint performance, they should be covered with the best possible product the market offers—currently, a chlorinated rubber base paint.

By nature, chlorinated rubber base paints are thoroughly waterproof and chemical resistant, and remain unaffected in the presence of hydrogen sulphide gas. A wide range of colors is available. Their performance will far exceed the best drying oil products on the market.

Chlorinated rubber base enamels are easily applied, either by brush or spray, and will not, as some believe, drag under the brush or clog spray equipment. Finish coats can be thinned as much as 10 to 15 per cent with specialized thinner, without losing any of their protective values. There are available chlorinated rubber base products incorporating fungicidal agents, which will inhibit, to a large extent, mold and fungus growths that discolor paint films. It should be remembered that the oils in oil base paint products dry out, the "crazed" or "checked" surfaces becoming vulnerable to attack from dampness and moisture, causing the paint to flake or crack off the surface as the paint film is undermined from the rear.

Such conditions have been observed in many of the sewage treatment plants visited in the Central States area. Much of the skepticism plant superintendents hold toward the newer types of paints and coatings is probably due to their being forced to see such conditions face to face for 6 days a week.

Often, the clarity of the final effluent is of concern to plant superintendents. Light-colored chlorinated rubber base paint on final effluent channels and weirs will provide an excellent background for visual checking of effluent clarity.

Preparation for Painting

There is no substitute for adequate preparation of surfaces for painting. All loose scale, rust, or scaling paint must be removed by wire-brushing, scraping, sandpapering, or sandblasting before repainting. No paint on the market will adhere satisfactorily to surfaces that are loose, poorly cleaned, or not firmly adherent.

Only the best paint products available should be used. Painting should be done only when surfaces are thoroughly dry, not in damp or wet weather. The manufacturer's directions should be followed as to the number of coats to be applied, the type of primer to be utilized, if any, and the method of thinning. The results will be lower painting costs, lower repair and replacement costs, and a knowledge that everything possible has been done to protect expensive installations against the ravages of deterioration.

TIPS AND QUIPS

Vacuum Filtering Ideas

Fellow sufferers from "vacuum sludgitis" may find some helpful hints in the 1946–47 annual report of J. W. Johnson, superintendent at the Buffalo, N. Y., sewage treatment works. Concerning his problems and the solutions thereto, Mr. Johnson says:

"Wide variations in sludge characteristics made vacuum filtration unsatisfactory most of the time. Lack of heat transfer and the presence of toxic wastes reduced gas production, causing a marked stratification of the digestion tank contents. Dosage of conditioning chemicals greatly exceeded the amounts of past years. Unreasonable amounts of both lime and ferric chloride were required to produce only a subnormal filter yield because of the extreme variations in solids content of the tank sludge.

"Before the first of the year the chemical concern that had supplied ferric chloride since the plant began operations advised that they were no longer interested in selling this commodity. When other sources were not to be found, an extensive search

was made for a suitable substitute. Field and laboratory tests indicated that there was sufficient aluminum chloride present in a waste discharge of a local chemical industry to be used for this purpose. Presence of an oily residue in the material required that it be processed, or that the rubber-lined storage tanks and process lines be further protected against disintegration. Consideration was given to a settling basin and to the examination of several types of lining material, several of which were subjected to immersion tests. Indications are that the aluminum chloride will be used pending satisfactory negotiations with the producer.

"Because of the poor workmanship of ready-made filter covers, it was found expedient to buy the material in bolts and have it cut and sewn locally. A second plastic take-off blade was set up on one of the filters, as it has been found that the first such blade installed was less severe in wearing the surface of the cloth and could be more easily adjusted than the original steel blade. To prevent bulging of the cloth at the take-off point, holding wires were run horizontally as well as vertically, but the procedure was stopped when no greater operation life was realized."

Note on Interior Decoration

Been wondering how to paint the inside of tanks without spending time, labor, or money? Don't laugh. According to an item in the June, 1949, issue of *Plain Sediment*, published by the West Virginia Sewage and Industrial Wastes Association, the Imhoff tank at the Westinghouse plant in Fairmount, W. Va., was redecorated the easy, painless way. Some kind soul discharged several hundred gallons of lacquer into the sanitary sewer, resulting in a thorough interior painting of the entire plant.

One Thing Leads to Another

If it isn't one thing, it's two others —as Charles Clem, Superintendent of Sewage Treatment at Buchanan, Mich., found out during the past winter, when he had his hands full with digester troubles. His experiences, as reported in the April issue of the *Michigan Sewage Works Bulletin*, read like the makings for a nervous breakdown.

In November, 1948, the behavior of the digester hot water circulation system indicated that there was a leak somewhere. However, the question arose as to whether it was inside the digester or in the 125 ft. of pipe buried between the digester and the control building. Preliminary investigations indicated that it was in the digester. Therefore, the digester had to be emptied—all 200,000 gal. The sludge, of course, could not be put into the river, so it was finally decided to lagoon it and save enough for seed.

Mr. Clem, aided by F. E. Fulmer, engineer with Clyde Williams and Associates of South Bend, Ind., and some guidance from the Division of Engineering, Michigan Department of Health, went to work with a will. This was the biggest problem he had tackled—and he's had some other tough ones—since taking over the plant early in 1948. Here is the story in his own words:

"Started January 8, grading for a lagoon area for the digester sludge. Approximately 20,000 sq. ft. was needed, filled to from 12 to 18 in. deep. We had difficulty holding the lagoon dikes due to warm weather, heavy rains, and tree roots. We drained the digester o.k. and saved one final tank full of digester sludge for seed. One primary settling tank was also used to store raw sludge while working on the digester. After draining the digester as far as possible, it was refilled with water pumped in from the creek to purge the tank of all gas. We drained it again and then, using a live rabbit, tested it and found it free of all gas. We then went down in the tank for the first time and found from 5 to 6 ft. of sand, gravel, and heavy sludge in the bottom—too heavy to flow out the drawoff.

"Next, we had to start flushing and cutting the heavy sludge with water. Water was pumped from the creek through a 4-in. fire hose with good pressure, along

with raw sewage pumped in with the primary sludge pump. It was a slow and tedious job, due to the grit, the heavy sludge, and the design of the tank drawoff line. After flushing out the sand, etc., the heating coils in the digester could be checked. About ⅛ to ¼ in. of scale was found on the heating coil, but after cleaning off the scale, the pipe was found to be in excellent condition. One 6-ft. length of pipe was removed from the heating coils and examined thoroughly inside and out. It was decided that the pipe did not need replacing as it should last several more years, at which time the sand, gravel, etc., should be cleaned out of the digester again so as to keep from getting too much weight on the coils, which are within 6 ft. of the bottom.

"The coil leak then was found to be underground outside the digester. Therefore, all pipe, including the gas line, was replaced with 2-in. copper tubing. The old pipe was completely rusted out and was not even good for junk, due to improper drainage of the pipe line.

Floating Cover Freezes Up

"During the first part of the digester job we ran into a peculiar and dangerous experience. During a cold spell and with no heat in digester, the gas holder froze in its high position. The gas was burned out, the gas pressure going down to nothing or nearly so, until the gas furnace went out. Air somehow got in the gas line and with the proper mixture of digester gas, sulfur and other oxides collected on the inside walls of the gas pipe ignited and burned inside the pipe within the building. [Iron sulfide often will "burn" spontaneously when exposed to air, and sometimes even in a practically oxygen-free atmosphere. Precautions must be taken in dismantling old sludge gas piping lest rapid oxidation of the iron sulfide deposits burn the workers or cause a structural fire or explosion.—Ed.] The fire was located between the digester and the waste gas burner, about 3 ft. from the waste gas control. It burned itself out in 15 or 20 min., however, confining itself to about 4 ft. of the pipe. Why it didn't follow back to the digester and possibly explode, I don't know. It's possible there was a sudden build up of gas pressure or a complete lack of gas in the line, the gas escaping through the water seal at the digester. The gas cover was hurriedly chopped and thawed loose and dropped down again in the water, thus building up gas pressure. It was kept thawed out after that until we opened up the digester.

"Several things were learned from these experiences: 1) All gas lines should be removed and cleaned at least once every 6 to 8 years; 2) The gas lines to the waste gas burner, besides having a drip trap, should have a large enough opening to clean out any sand from briquettes, rust, and other dirt that would otherwise plug the pipe line; 3) Where it is possible to get a crane close enough to a digester it would be much faster, cheaper, and easier, after removing the gas dome, to use a clamshell bucket to remove all sand, gravel, and heavy sludge from the digester; and 4) The digester drawoff line should be installed so that it will draw off all water, etc., to the bottom of the digester and not within 3 ft. from the bottom at the outside wall of the tank and 4 or 4½ ft. in the center of the tank as was the case at Buchanan. If properly designed, the tank could have been completely drained without too much trouble, or perhaps without the use of a crane.

"However, after 2 months, the job is done and we are much the wiser for our experiences. At least we will know what we are up against the next time it has to be done."

It Couldn't Happen

Grave doubts assailed the minds of sewer maintenance supervisors when a manhole cover blew up recently in Boston, Mass. No one was injured, despite the terrific blast and 50-ft. high flames, but the incident was reported over the major press association wires. It seems that when the cover was found, quite some time after the explosion, it was of a "blastproof" type!

Oil Slicks

Of the many good oil problem ideas exchanged during the Operators' Breakfast at the recent Central States Sewage Works Association meeting in

Chicago (June 17–18), a few were especially noteworthy. From the few notes your reporter was able to scribble between "passing the salt" and trying to catch the punch lines of the stories being told around the table, the following are offered for what use or adaptation may be made of them.

In one city, grease from brass machining operations completely plugged manholes as well as sewers. The discharge was eliminated by cooperation of the industry involved, through installation on each machine of a grease trap made in the shop from discarded oil drums.

The same community about once a year employs a man selected on the basis of both his tact and knowledge of the city and its industry, as a "good-will ambassador." Equipped with proper credentials and with placards containing the printed ordinance, he visits each industrial plant and commercial establishment, checks the pollutional sources with the proprietor or manager, and discusses with that representative any violations or questions of application of the ordinance. For each visit he makes a very brief report, sees that the ordinance is properly posted, and obtains a receipt of the call from the party contacted. Industrial cooperation in this community has been almost perfect since this system was put into effect, with even the most minor of accidental spillages being reported to the sewage treatment plant immediately by the offender.

An excellent cooperative program has been worked out, also, with the police and fire departments, who call the treatment plant immediately should a spillage of gasoline or oil occur where it can reach the catch basins of the combined sewer system. In this way, plant personnel can be prepared to deal with the situation when it does reach the plant.

Another suggestion worthy of note is that of providing industrial foam type extinguishers in the plant wet well. With such equipment on hand, most gasoline or oil fires can be circumvented simply by foaming the sewage surface to prevent oxygen from reaching the ignitable material until it is removed.

One superintendent, having found a gas-station proprietor pumping the sludge from his gasoline tanks to the sewers despite previous warnings, said nothing, but quietly arranged for the safety units of his police, fire, street, water, and sewer departments all to converge on the offender simultaneously. The resulting psychological effect on the filling station operator was no less than terrific, and the ensuing publicity was extremely beneficial in its reaction on proprietors of similar establishments.

Sewered Gas

From Knoxville, Tenn., comes a report of methane, produced in the sanitary fill, finding its way into a nearby sewer in sufficient concentration to burn like a Bunsen burner when ignited at a manhole.

Moral: a sewer in or near a sanitary fill may turn out to be the fuze on a bomb.

Plenty of Green Stuff

On the day that Roy Binder recently celebrated his eighth anniversary as operator of the Hays, Kansas, sewage treatment plant he began to wonder if someone was playing a practical joke on him. The reason was a $10 bill in the influent. However, all is not gold that glitters, and the greenback turned out to be toy money.

But by no stretch of the imagination can the rest of Mr. Binder's green stuff —his garden at the plant—be considered a joke. In fact, with prices where they are it's a wonderful help. Listed in a recent newspaper article about the plant and its operation are such fruit trees as three varieties of

plum, peach, apple, cherry, and plum-cherry. In the laboratory there are two small lemon trees, which bloomed and are expected to bear fruit this year. Bush fruits include blackberry, boysenberry, and red raspberry, to say nothing of two large strawberry beds from which 4 qt. of berries are picked every day. In the vegetable section of the garden are potatoes, tomatoes, beans, carrots, lettuce, radishes, cabbages, cucumbers, peppers, horseradish, and egg plant. Last year the cucumber bed yielded more than 30 bushels of the finest "cukes" imaginable.

Although the garden is primarily a hobby, it also serves as a good sales demonstration for acquainting visitors with the fertilizer value of sludge, thus assuring a steady disposal market. In addition, the free distribution of thousands of sturdy tomato plants has created an untold wealth of good-will among the townspeople.

No Heat Needed

A really "hot" load of sludge was handled on August 29, 1948, at the Marion, Indiana, plant when 8 tons of spoiled red papers were put through the municipal garbage grinder and pumped to the plant digesters. No further mention is made in the 1948 operating report log concerning the charge or its effect on tank performance, so it must be assumed that despite the summer heat, the stuff was not "too hot to handle."

OPENING FOR OPERATOR-INSTRUCTOR

Unusual opportunity for experienced activated sludge plant operator to initiate operation of a new plant in the Southeast and train permanent staff. Salary $4,200. Present position for one year only, but similar engagements are expected to be available for several years in the future as new plants are completed under construction program now underway.

Applications should be sent to Sewage Works Journal, 325 Illinois Building, Champaign, Illinois, giving complete details as to training and experience.

Editorials

THE SEWER ORDINANCE MANUAL

Until now, much has been said and written but little done about the need for sound and practical municipal ordinances for controlling the use of public sewers. The Federation's Manual of Sewage Works Practice No. 3 entitled "Municipal Sewer Ordinances"—modest in size but dynamic in purpose—will reach the distribution stage about the time this issue makes it appearance. It is the third special publication to be presented by the Federation this year.

The sewer ordinance manual will more than justify its production if it does nothing more than remind municipal officials either that (a) no sewer system regulations are in force, or (b) that existing regulations should be reviewed and brought up to date. Consequently, Mr. Superintendent, you will do well to see that copies of the manual are read by influential members of your Council, Commission or Board of Trustees. He who heeds not this advice has no right to complain henceforth about how much of what comes down from this or that factory to upset his sewage treatment plant!

But the ordinance manual is more than just a deficiency reminder. The original draft of the bulletin was rewritten three times on the basis of criticism received from more than a hundred authoritative reviewers. Many existing regulations and recommended model ordinances were studied, evaluated, and their strong points noted. The technical literature has been searched for pertinent documentation. The result is a compilation of sound principles, assembled in a way that is intended to make them readily applicable in the field.

The manual was developed by the Sewage Works Practice Subcommittee on Municipal Sewer Ordinances, consisting of Don E. Bloodgood, Chairman, H. E. Babbitt, F. J. Biele, R. F. Brown, M. M. Cohn, C. A. Davis, C. E. Keefer, A. F. Lehman, A. H. Niles, B. A. Poole, J. J. Quinn, and C. L. Siebert. The Federation acknowledges with gratitude the 3 years of effort by this committee, as well as the constructive advice of those who reviewed the preliminary drafts.

The usefulness of the ordinance manual is not limited to municipalities. It holds substantial value for the guidance of industry, which may not be appreciated in the first reaction that industrial wastes are subjected to control. The industry contributing wastes that interfere with the operation of the municipal sewage works has not solved its problem, for such conditions will not be permitted to exist for long. The real solution is reached only when there is close collaboration between the industry and the municipality, to the end that the public sewage works are used to their reasonable capacity, and without detriment to their effectiveness. The manual urges such coöperative approach.

"We have an ordinance, but *they* don't enforce it," is a common plaint of operators who are plagued by conditions resulting from inadequate sewer system regulation. Too true; it is contrary to human nature to submit to regulation if compliance is inconvenient and if there is no punishment for violation. The manual recognizes this problem by recommending that the sewage works superintendent be given the responsibility of administering the ordinance. Even when he does not have direct enforcement authority, however, the superintendent is remiss if he fails to apply himself persistently toward securing appropriate enforcement of existing regulations.

A municipal governing body that has been properly advised of the consequences of inaction will furnish all the enforcement support that is needed. The ordinance manual purposely emphasizes the consequences of inadequate regulation, so that it may be used by sewage works administration personnel to gain the interest and backing of municipal officials.

The full value and significance of the sewer ordinance manual will probably not be generally appreciated for a long time. To date we have been so engrossed with scientific and technical details of waste disposal practice that an exceedingly important aspect has largely been taken for granted. What does it avail us to pay meticulous attention to design rates and capacities, and to the selection of processes and equipment, while doing little or nothing to eliminate unnecessary imposition on the sewage works in the way of the character of the load that it will actually receive?

A good sewer ordinance is nothing more than a set of reasonable specifications of the quality of the raw material that can be handled safely and properly by the municipal system. Such an ordinance benefits and protects everyone concerned with the facilities; the user, the taxpayer, the bond holder, the municipal authority, and the designer.

The Federation is eminently proud of its Manual of Practice No. 3!

W. H. W.

THE BOSTON MEETING

It seems to us that the Twenty-second Annual Meeting of the Federation at Boston on October 17–20 offers full measure of every ingredient that is essential to an outstanding national convention.

New England in October is spectacular in its scenic beauty, assuring a delightful trip. Boston itself is unique for the number and caliber of its historic and cultural attractions. So much for the setting.

The technical program this year speaks for itself (see page 931). It has balanced diversity, emphasizing topics on which information is needed. Extraordinary attention will be given to the presentation of the program with smoothness and precision.

The social events are essentially informal, to encourage relaxation and fellowship. Plenty of opportunity for visiting with old friends and making new ones.

Catalyzing the reaction is the determination of the New England Sewage Works Association to meet every responsibility of the perfect host. The formula has everything, and a grand convention is in store for everyone who attends.

W. H. W.

Proceedings of Member Associations

VIRGINIA INDUSTRIAL WASTES AND SEWAGE WORKS ASSOCIATION

Third Annual Meeting

Natural Bridge, Virginia, March 31–April 1, 1949

The Virginia Industrial Wastes and Sewage Works Association held its Third Annual Meeting at the Natural Bridge Hotel, Natural Bridge, Va., March 31–April 1, 1949. The record registration of 129 delegates taxed housing facilities at the popular tourist attraction to the limit.

Officially opening the meeting on March 31, President Bryant L. Strother introduced B. G. Locher, Glasgow member of the Virginia House of Delegates, who gave a short address of welcome. He emphasized that the Association, in carrying out its objectives, could play an important part in furthering the job of stream pollution abatement in Virginia. At the luncheon session, which followed, Vice-President A. H. Niles, of the Federation of Sewage Works Associations, presented a short resume of recent Federation activities.

A highlight of the meeting was an inspection trip, in the afternoon of March 31, to the James Lees and Sons Co. rug mill in Glasgow. After a short and pleasant drive through the mountains to the plant, meeting delegates inspected the waste treatment facilities installed when the company, early in 1946, decided to add wool scouring and dyeing operations to its existing rug weaving plant.

After returning from the inspection trip, the hungry delegates enjoyed a "smorgasbord" dinner and a dance that occupied the remainder of the evening.

Technical sessions during the morning of April 1 were held in the Auditorium. First paper to be presented was "Sewage Treatment Planning for Bristol," by M. T. Singleton, consulting engineer, Atlanta, Ga. Stressing the problems, both technical and political, which had to be overcome in reaching a solution, he stated that a treatment plant proposed would eliminate most industrial and virtually all sewage pollution of Beaver Creek. Located on the border of Virginia-Tennessee, Bristol is really two cities, with a separate government in each state. The treatment plant will be in Tennessee. Money to construct the plant will be obtained from a bond issue approved in November. The plant will employ high-rate trickling filters, followed by activated sludge treatment, to produce a high quality effluent for discharge to the small stream.

A panel discussion was presented on "The Cooperative Approach to Stream Pollution Studies in Virginia," with A. H. Paessler, acting executive secretary, Virginia State Water Control Board; H. E. Lordley, assistant director of the Richmond Department of Public Utilities; and Roy McCracken, sanitary engineer, E. I. duPont de Nemours & Co., composing the panel, and J. M. Morgan, instructor in sanitary engineering at the Virginia Military Institute, discussing the papers presented.

In a paper on "Milk Wastes Disposal," H. Clifford Mitchell, Chief, Bureau of Sanitation, Department of Public Health, City of Richmond, emphasized that milk plants, as well as other small industries, need technical help at reasonable cost in solving their

stream pollution problems. Such help is available through national and regional associations of the various industries (for example, the Task Committee on Dairy Waste Disposal, sponsored by associations representing several segments of the dairy industry).

At the business session the Association constitution was amended to conform with the Federation's new 1950 dues schedule for Active members, necessitated by increasing operating costs and monthly publication of SEWAGE WORKS JOURNAL.

Officers re-elected to serve for 1949–50 are:

President: Bryant W. Strother, Richmond, Va.
Vice-President: J. A. Rines, Blacksburg, Va.
Secretary-Treasurer: A. H. Paessler, Richmond, Va.

A. H. PAESSLER,
Secretary-Treasurer

MICHIGAN SEWAGE WORKS ASSOCIATION

24th Annual Conference

Traverse City, Michigan, May 23–25, 1949

The 24th Annual Conference of the Michigan Sewage Works Association was held at the Park Place Hotel, Traverse City, Mich., May 23–25, 1949. The attendance of 166 men set a new record for the Association. The widely diversified technical program, designed to provoke the interest of sewage plant personnel, industrial waste disposal operators, consulting engineers, and municipal officials, attracted many from each of these groups. Illustrative of this broadened interest is the attendance by representatives of 14 different companies concerned with industrial waste disposal. General Motors alone had 27 men in attendance, representing 12 separate divisions of the corporation, as well as the general administrative office. Likewise, in the municipal group, increased attendance by councilmen and administrative officers was noted.

The first technical session, held on the afternoon of May 23, was of general interest to all. It included a discussion entitled "A Reporter Looks at Pollution," by Jack VanCoevering, wildlife editor of the *Detroit Free Press;* "Financing Sewage Disposal Systems," by Claude H. Stevens, Detroit lawyer; and a comprehensive "Analysis of the Combined Project for Sewage Collection, Flood Protection, Garbage Disposal and Sewage Treatment for Saginaw, Michigan," by George E. Hubbell, consulting engineer, Detroit.

The technical sessions on May 24 were devoted to subjects of interest primarily to operators of sewage treatment plants. The folowing program was presented: "Methods of Sludge Heating," by R. A. Greene, superintendent of sewage treatment, Jackson, Mich.; "Air Diffusion Practices at Pontiac," by Floyd L. Vermette, engineer of sewage treatment, Pontiac; "The Federal Pollution Control Program," by S. C. Martin, Great Lakes basin engineer, U. S. Public Health Service; "Characteristics of Storm Water Flows From Combined Sewers in Detroit," by Clyde L. Palmer, engineer, Department of Public Works, Detroit, with discussion by L. F. Oeming, sanitary engineer of the Michigan Water Resources Commission; "Use of Sewers," by Arthur H. Niles, superintendent of sewage treatment, Toledo, Ohio.

Subjects presented at the technical sessions on May 25 were related primarily to special problems of interest

primarily to industrial waste personnel. A. A. Hilgart, staff engineer of the Upjohn Company, Kalamazoo, discussed "Problems in the Design and Operation of a Wastes Treatment Plant for Penicillin and Streptomycin Wastes." "The Use of Pickling Liquors from the Iron and Steel Industry for Sludge Conditioning," was discussed by Michael A. Groen, superintendent of sewage treatment, Dearborn. C. A. Habermehl, sanitary chemist of the Detroit sewage treatment works, and J. E. Cooper, supervisor of the Water and Wastes Section, Process Engineering Laboratory, Ford Motor Company, further discussed this subject. "The Treatment of Cyanide Wastes from the Electro-plating Industry," was discussed by A. N. Corcoran, sanitary engineer of the Michigan Water Resources Commission. W. D. Hatfield, superintendent of the Decatur, Ill., sanitary district, described "Limitations, Interferences, and Precautions in Analytical Determinations for Certain Toxic Wastes." The technical sessions were concluded by a panel composed of seven men of the General Motors Corporation, led by L. A. Danse, supervisor of metals and processes, on the subject "Disposal of Oil Emulsions."

About 100 men attended the annual smoker, for which entertainment was co-sponsored by the Water and Sewage Manufacturers' Association. They were entertained by movies taken in Alaska and Michigan by Philip D. Rich, editor and owner of the *Midland Daily News*. Other entertainment events included the annual banquet, attended by a total of 129, including 22 ladies. A most interesting discussion of scientific methods of criminal investigations was presented by C. W. Muehlberger, toxicologist of the Michigan Department of Health. A very interesting and enjoyable schedule of activities for the ladies who attended the conference elicited much favorable comment and is indicative that many more ladies will attend next year.

At the annual business meeting, it was reported that the membership voted unanimously except 1 in favor of amending the Association constitution to include a provision for increase of dues in keeping with current Federation policy. The revised constitution was adopted as of April 15, 1949.

Officers elected for the coming year were:

President: George E. Hubbell, Detroit.
Vice-President: Dale W. Granger, Lansing.
Secretary-Treasurer: Donald M. Pierce, Lansing.
FSWA Director: L. F. Oeming, Lansing.

DONALD M. PIERCE,
Secretary-Treasurer

FLORIDA SEWAGE WORKS ASSOCIATION

Seventh Annual Meeting

Gainesville, Florida, June 6–11, 1949

The Seventh Annual Meeting of the Florida Sewage Works Association was held on the University of Florida campus at Gainesville, June 6–11, 1949. The meeting was held jointly with the 17th Annual Florida Short Course on Water Supply and Sewage Treatment. Enrollment at the short course totaled 160, of whom 49 were Association members.

The 40-hr. short course was divided equally between conferences on fundamentals and individual work under close supervision in the new University laboratories. The four sections into which the course was divided included

one on sewage, and three (elementary, intermediate, and advanced) on water.

For the first time, it is believed, two presidents of national associations—the American Water Works Association and the Federation of Sewage Works Associations—were together at a short course. Joining A. P. Black, of A. W. W. A., was V. M. Ehlers, president of the Federation, who made the major address of the opening ceremonies. On this occasion also, awards were presented for outstanding distinction for the best sewage treatment plant and the best water treatment plant of the year. These awards were received, respectively, by M. E. Dawkins, superintendent, University of Florida sewage treatment plant, and Thomas Paul, superintendent, Bradenton water plant.

A technical session was held in the forenoon of June 7, presided over by Perry M. Teeple, regional sanitary engineer for Northeast Florida, in which the Florida Sewage Works Association presented four technical talks as follows:

"Progress Since July 1948 by the Sanitary Engineering Research Division of the Engineering Experiment Station of the University of Florida," by Professor C. D. Williams, Gainesville.

"Early Operating Experiences at the Daytona Beach Sewage Treatment Plant," by L. H. Scott, field engineer, Infilco, Inc.

"Some Effects of Citrus Wastes upon Sewage Treatment by Florida Municipalities," by Wylie W. Gillespie, Jacksonville.

"Facts About Actual Use of Transite Pipe for Sewerage Purposes," by W. B. Gibson, Johns-Manville Sales Corp., Altanta, Ga.

Inspection of the University sewage treatment plant followed the technical session. Inspection was also made during the week of the recently completed Gainesville water treatment plant. Examinations and ratings of Class "B," "C," and "D" water works operators' licenses and for Class "B" and "C" sewage works operators' licenses were held on the closing day.

At the business session accompanying the dinner meeting of the Association, no objection was raised to the proposed 1950 raise in Federation dues from $3 to $5. Association officers elected for 1949–50 were:

President: S. Keith Keller, Clearwater.
Vice-President: W. J. Parks, Jacksonville.
Secretary-Treasurer: Perry M. Teeple, Jacksonville.

PERRY M. TEEPLE,
Secretary-Treasurer.

OHIO SEWAGE AND INDUSTRIAL WASTES TREATMENT CONFERENCE

23rd Annual Meeting

Cleveland, Ohio, June 22–24, 1949

The 23rd Annual Meeting of the Ohio Sewage and Industrial Wastes Treatment Conference was held at the Hotel Carter, Cleveland, Ohio, June 22–24, 1949. A total of 233 men and approximately 40 ladies registered for the meeting, of whom a large proportion were representatives of industries active in waste pollution abatement.

The morning session on June 22 was devoted to a Manufacturers' Forum, presided over by F. D. Young, Cleveland, at which representatives of the various manufacturers of special equipment and supplies discussed maintenance of sewage gas protection devices, dual-fuel engines, and sewage and sludge pump packings.

During a short business meeting, at which Emil Crown, Cleveland director of public utilities, welcomed the delegates, and A. H. Niles, vice-president of the Federation, spoke on Federation affairs, the necessary constitutional changes were made to accommodate the change in officers (election of a second vice-chairman) and in dues. The latter were raised from $5 to $7.50 to conform to the new Federation dues schedule for 1950.

Officers elected for 1949–50 were:

Chairman: W. R. Bowman, Findlay.
1st Vice-Chairman: H. S. Kline, Dayton.
2nd Vice-Chairman: W. E. Gerdel, Cleveland.
Secretary-Treasurer: G. A. Hall, Columbus.

The balance of the afternoon was devoted to such papers of general interest as "Lubrication," by C. R. Schmitt, Cleveland; "Sewage Treatment Program of the City of Cleveland," by F. S. Palocsay, Cleveland; and "Tannin Interference with Dissolved Oxygen Determinations," by W. D. Sheets, Worthington, Ohio; followed by an inspection of the Cleveland Easterly and Westerly sewage treatment plants.

An entertaining evening was enjoyed by the men at a Smoker sponsored by the Water and Sewage Works Manufacturers' Association, while the ladies had their own "Ladies Only Night" elsewhere in the headquarters hotel.

An Operators' Forum on the morning of June 23 was of the usual high calibre and evoked a great deal of stimulating discussion. This was followed by discussions on "Status of Federal and State Legislation on Stream Pollution Abatement," with M. LeBosquet, Jr., representing the U. S. P. H. S.; E. J. Cleary, the Ohio River Valley Water Sanitation Commission; and F. H. Waring, the State of Ohio.

The afternoon program on June 23 was divided into concurrent sessions on sewage treatment and industrial wastes treatment. Papers presented at the sewage treatment session included:

"Factors Affecting Sludge Force Mains," by John R. Wolfs, Cleveland;

"Preventive Maintenance," by Elmer Pollex, Toledo;

"Report of Short School," by R. F. Snyder, Massillon;

"Operation of Heaters and Heat Exchangers for Controlled Digestion," by L. C. Huffman, Dayton;

"One Year of Operation at Crestline's New Activated Sludge Plant," by George R. Cunitz, Marion; and a forum for discussion of matters brought up by the attending delegates.

The industrial wastes treatment symposium included the following papers:

"Oil Separator Operation," by L. B. Perillo, Cleveland;

"Disposal of Oil Emulsions," by Herman W. Bareus, Philadelphia, Pa.;

"Acid Iron Wastes Neutralization," by R. D. Hoak, Pittsburgh, Pa.;

"Acid Iron Wastes Neutralization at Copperweld Steel Co.," by Roy F. Lab, Warren, Ohio;

"Phenol Recovery at By-Product Coke Plants," by Frank Wilks, New Miami, N. B. Thompson, Lorain, and Walter Carbone, Ironton;

"Biological Treatment of Phenolic Wastes," by T. J. Powers, Midland, Mich.; and

"Phenol Analyses," by E. G. Will, Columbus.

At the evening banquet session a movie entitled "Ohio's Natural Resources" was shown.

Papers at the June 24 morning session included:

"Accidents Just Dont' Happen," by Ben H. Barton, Findlay;

"Activated Sludge Treatment of Rendering Plant Wastes," by F. S. Wintzer, Wapakoneta;

"Effect of Zinc on Sludge Digestion," by M. L. Granstrom, Cleveland; and

"Ordinances Governing Use of Sewers and Regulations on Garbage Grinders," by A. H. Niles, Toledo.

An "open house" was held at the Cleveland Southerly sewage treatment plant the afternoon of June 24 to close the meeting.

G. A. HALL,
Secretary-Treasurer.

NEW YORK STATE SEWAGE WORKS ASSOCIATION

1949 Spring Meeting

Kingston, New York, June 6–7, 1949

The 1949 Spring Meeting of the New York State Sewage Works Association was held at the Hotel Governor Clinton, Kingston, New York, June 6–7, 1949. Registration included 16 ladies and 127 men, a total of 143.

The first morning's program included a short business meeting and the following technical program:

"High Rate Filtration at Liberty, N. Y.," by W. A. Hardenbergh, editor, *Public Works*, New York City; and John Lawrence, Olney Borden, and Harry Eichenauer, all of Liberty, and, respectively, superintendent of public works, consulting engineer, and sewage treatment plant operator. The paper was discussed by W. W. Sanderson, associate sanitary chemist, State Department of Health, Albany.

"Digestion of Combined Tannery and Sewage Sludge at Gloversville, N. Y.," by Morrell Vrooman, consulting engineer, and Virgil Ehle, associate, Gloversville. Discussion was by Willard R. Smith, superintendent of sewage treatment, Gloversville.

The afternoon program included the following papers and discussions:

"Automatic Chlorination of Sewage," by H. B. Snyder, sanitary engineer, Wallace & Tiernan Company, Newark, N. J.

"Stream Standards and Their Practical Application," by Charles C. Agar, chief, Stream Pollution Section, State Department of Health, Albany.

"Economic Methods for Treatment of Industrial Waste," by William A. Ryan, sanitary chemist, Rochester. Discussion was by Glenn Searls, supervisor of sewage treatment, Rochester.

"Treatment of Sewage from Combined and Separate Sanitary Sewers at Kingston, N. Y." by E. I. McCaffrey, consulting engineer, Kingston.

At the dinner meeting on June 6, the members and their guests were welcomed to the city by Mayor Oscar V. Newkirk. Following the dinner J. A. Salvato, Jr., chairman of the Rating Committee, presented the Association's awards—a loving cup to S. E. Konwinski for his report on the Dunkirk, N. Y., sewage treatment works; and a certificate to L. A. Sammis, a previous award winner, for his report on the sewage treatment works of the Pilgrim State Hospital. Entertainment was provided by B. H. Swab of Toledo, Ohio, who presented an interesting colored travel film.

The morning program of June 7 was given over entirely to a panel discussion on "Screening, Shredding, Comminuting, and Grit Removal." The panel leader was S. T. Barker, chief of the sewerage and wastes section, State Department of Health, Albany, N. Y. Participating with him on the panel were: A. J. Fischer, The Dorr Co., New York City; J. J. Gilbert, Link-Belt Co., Philadelphia, Pa.; J. M. MacCrea, Chicago Pump Co., Syracuse; Uhl T. Mann, superintendent of Ley Creek Plant, Syracuse; A. J. Scanlon, chief of maintenance and operations, Bureau of Sewage Disposal Oper-

ations, Dept. of Public Works, New York City; H. M. Weil, Chain Belt Co., New York City; and Newell L. Nussbaumer, consulting engineer, Buffalo.

The afternoon was devoted to an inspection of the Kingston sewage treatment works.

Special entertainment in the form of a guided tour of the several historic spots of interest in and around Kingston was provided for the attending lady guests.

RALPH C. SWEENEY,
Secretary.

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Iowa Sewage Works Association	Hotel Kirkwood, Des Moines, Ia.	Sept. 20–22, 1949
Rocky Mountain Sewage Works Association	Acacia Hotel, Colorado Springs, Colo.	Sept. 21, 1949
Georgia Water and Sewage Works Association	Georgia Institute of Technology Atlanta, Ga.	Sept. 21–23, 1949
West Virginia Industrial Wastes and Sewage Works Association	Oglebay Park, Wheeling, W. Va.	Sept. 21–23, 1949
Canadian Institute on Sewage and Sanitation	McIntyre Arena, Schumacher, Ontario, Canada	Sept. 26–28, 1949
South Dakota Sewage and Water Works Conference	Alex Johnson Hotel, Rapid City, S. Dak.	Sept. 28–30, 1949
Federation of Sewage Works Associations	**Hotel Statler, Boston, Mass.**	**Oct. 17–20, 1949**
New England Sewage Works Association	Hotel Statler, Boston, Mass.	Oct. 17–20, 1949
Kentucky-Tennessee Industrial Wastes and Sewage Works Association	Lafayette and Phoenix Hotels, Lexington, Ky.	Oct. 31–Nov. 2, 1949
North Carolina Sewage Works Association	Highland Pines Inn, Southern Pines, N. C.	Nov. 7–9, 1949
Arizona Sewage and Water Works Association	San Carlos Hotel, Yuma, Ariz.	Nov. 11–13, 1949

Federation Affairs

TWENTY-SECOND ANNUAL MEETING PREVIEW

Hotel Statler, Boston, Mass., October 17–20, 1949

★

In Conjunction With
Twenty-First Annual Meeting of
The New England Sewage Works Association

★

Highlighted by a technical program of noteworthy diversity and timeliness, the Federation's Twenty-Second Annual Meeting promises to challenge all previous meetings for top honors in interest to the Federation's membership. All of the many local arrangements necessary for a successful convention have been carefully attended by E. Sherman Chase and his host committee members of the New England Sewage Works Association, assuring, when coupled with the work of the program committee, a meeting of high technical quality and excellent social and entertainment value. Adding to the interest and enjoyment of the meeting will be the manufacturers' exhibit, which will provide an opportunity for Federation members to see and discuss the latest developments in sewage and industrial waste works equipment and supplies.

Following the precedent established in 1948, the program will extend over four days in order to include all of the top-notch features planned for the Twenty-Second Annual Meeting.

THE PROGRAM

MONDAY, OCTOBER 17

Morning

Registration—Mezzanine Lounge.

Inspection of Exhibits—Georgian Room.

Twenty-Second Annual Meeting Called to Order
President V. M. Ehlers.

Welcome to Boston
Walter H. Brown, Jr., President, New England Sewage Works Association.

Progress in Solving the Sewage Pollution Problems of the Massachusetts Metropolitan District
Karl R. Kennison, Chief Engineer, Metropolitan District Water Supply Commission, Boston.

Sewage Treatment and Disposal for Boston
Robert P. Shea, Sewer Division Engineer, Boston Public Works Department.

Afternoon

Bacterial Standards for Natural Waters
Abel Wolman, Professor of Sanitary Engineering, The Johns Hopkins University.
Discussion: A. H. Stevenson, Sanitary Engineer, U.S.P.H.S.

Application of Sodium Nitrate to the Androscoggin River
Walter A. Lawrance, Professor of Civil Engineering, Bates College.
Discussion: Harry W. Gehm, Technical Advisor, National Council for Stream Improvement.

Statistical Approach to Stream Pollution
C. J. Velz, Professor of Sanitary Engineering, Manhattan College.
Discussion: R. N. Clark, Chief Public Health Engineer, Tennessee Valley Authority.

Problems Relating to the Disposal of Sewage into Tidal Waters
R. G. Tyler, Professor of Civil Engineering, University of Washington.
Discussion: R. H. Gould, Director of Engineering, Department of Public Works, New York City.

Evening

RECEPTION—ENTERTAINMENT—Imperial Ballroom

TUESDAY, OCTOBER 18

Morning

Moving Picture—"A Tale of the Twin Cities"
Courtesy of the Minneapolis–St. Paul Sanitary District.

High Rate Trickling Filter Operation on Formaldehyde Wastes
B. W. Dickerson, Sanitary Engineer, Hercules Powder Co.
Discussion: H. Heukelekian, Research Engineer, Agricultural Experiment Station, Rutgers University.

Treatment of Distillery Wastes
A. B. Davidson, Sanitary Engineer, Schenley Distilleries.
Discussion: M. W. Tatlock, Consulting Engineer.

Treatment of Wastes from the Meat Packing Industry
Leland Bradney, Walter Nelson, and R. E. Bragstad, respectively, Chemist, Sewage Treatment Plant; Mechanical Superintendent, John Morrell & Co.; and City Engineer, Sioux Falls, S. Dak.
Discussion: Clair N. Sawyer, Professor of Civil and Sanitary Engineering, Mass. Inst. of Technology.

Industrial Wastes Disposal at Pittsburgh
J. F. Laboon, Chairman of the Board and Chief Engineer, Allegheny County Sanitary Authority, Pittsburgh.
Discussion: H. H. Black, Chief, Industrial Wastes Section, Environmental Health Center, U.S.P.H.S.

Noon

ANNUAL FEDERATION LUNCHEON
Address: "Sanitary Engineering in a Changing World"
Gordon M. Fair, Dean, Graduate School of Engineering, Harvard University.

Afternoon

Sewerage and Sewage Treatment in the Colne Valley, England
W. F. Brown, Chief Engineer, Colne Valley Sewerage Board, England.
Discussion: R. S. Rankin, Engineer, The Dorr Company.

Air Diffusers for Activated Sludge—Results of Comparative Tests and Studies
Norval E. Anderson, Engineer of Treatment Plant Design, Sanitary District of Chicago.
Discussion: John J. Wirts, Superintendent of Sewage Disposal, Cleveland, Ohio.

Mechanical Equipment in Sewage Treatment
Frank L. Flood, Consulting Engineer.
Discussion: Charles R. Velzy, Consulting Engineer.

Evening

TWENTIETH ANNIVERSARY DINNER, NEW ENGLAND SEWAGE WORKS ASSOCIATION—Northeastern University.

WEDNESDAY, OCTOBER 19

Morning

Moving Picture—"Training in Los Angeles"

The Training of Sewage Works Operators in the United States
William T. Ingram, Associate Professor of Public Health Engineering, New York University.
Discussion: Bernard S. Bush, District Engineer, Pennsylvania Department of Health.

Maintenance and Operation of Large Sewer Systems
T. A. Berrigan, Director and Chief Engineer, Sewer Division, Metropolitan District Commission, Boston.
Discussion: W. P. Gyatt, Superintendent of Sewage Treatment, Syracuse, N. Y.

Basic Research on Standard Methods
W. D. Hatfield, Superintendent, Sewage Treatment Plant, Decatur, Ill.

Afternoon

Inspection Trip
Nut Island Sewage Treatment Plant and Appurtenant Structures.
William T. Sedgwick Lab. of Sanitary Science, Mass. Inst. of Tech.
Proctor & Gamble Co. Soap Plant.

Evening

ANNUAL FEDERATION DINNER AND DANCE—Imperial Ballroom

THURSDAY, OCTOBER 20

Morning—Concurrent Sessions

The Operators' Forum

LeRoy W. Van Kleeck, Leader

To Lime or Not to Lime.
J. Henry L. Giles and Harry Schlenz.

Sewage Disposal vs. Sewage Utilization.
Willem Rudolfs and R. W. Rowen.

Laboratory Tests for the Small Plant Operator.
W. W. Sanderson and F. W. Jones.
What Operators Want in Sewage Plants.
Uhl T. Mann and J. K. Adams.
Design and Operation of Booster Sewage Pumping Stations.
Edwin Locke and Roger Esty.

The Industrial Wastes Forum

Stuart E. Coburn, Leader

Cannery, Milk, and Other Food Products
Charles C. Agar.
Chemical Wastes
Lyman Cox, R. W. Hess, and B. W. Dickerson.
Oil Refinery Wastes
R. F. Weston.
Paper Mill Wastes
W. A. Lawrance and Don E. Bloodgood.
Plating and Metallurgical Wastes
J. E. Cooper and W. S. Wise.
Textile Wastes
J. A. McCarthy and J. E. Geyer.
Tanning Wastes
T. R. Camp and H. F. Reuning

Afternoon

Special Inspection Trips

TECHNICAL PROGRAM COMMENTS

With the many varied interests of Federation members in mind, the Program Committee, under the leadership of F. W. Gilcreas, has developed a technical program of diversified and timely papers, to be presented and discussed by acknowledged leaders in their fields. Such topics as new developments, design and operation practices, industrial waste treatment, public relations, stream and tidal water standards, training of operators, and progress of the Federation's basic research project on standard methods, are represented.

A perennial headline feature of Federation programs—the Operators' Forum—will have a rival for attention this year in an Industrial Wastes Forum that will run concurrently on Thursday morning. Subjects for both forum sessions have been carefully selected to provoke active and productive round-table discussions.

Something worthwhile has been provided for everyone in the field, in keeping with the progressive outlook and expanding interests of the Federation.

SOCIAL FUNCTIONS

The Reception-Entertainment on Monday evening will open the social program and provide an excellent opportunity to get acquainted. An entertainment hour following the reception will feature Bradford Washburn, Director of the Boston Museum, in his illustrated lecture on "Operation White Tower," the story of a scientific expedition to the top of Mt. McKinley. Later in the evening the manufacturers' exhibit will be open.

Principal speaker at the Federation Luncheon on Tuesday will be Dean Gordon M. Fair, Harvard Graduate School of Engineering, whose subject, "Sanitary Engineering in a Changing World," should be of interest to everyone in the field. As usual, special tables will be reserved at the luncheon for the Quarter Century Operators' Club.

Highlight event of the social program will be the Annual Federation Dinner and Dance on Wednesday evening. A feature of every annual meeting, the dinner hour is planned to include music and entertainment suitable to the occasion, followed by presentation of the Federation's annual awards. Dancing to an excellent orchestra will afford pleasurable entertainmnet for the remainder of the evening. As in previous years, dress will be optional.

The New England Sewage Works Association dinner on Tuesday evening has been arranged as a delayed celebration of the host association's twentieth anniversary and will be limited largely to members of the New England Association and their guests. However, a few extra tickets will be available. A feature of this event will be an illustrated travelogue by E. Sherman Chase of his recent trip to Europe.

LADIES' ENTERTAINMENT

Special entertainment provided for the ladies attending the convention should make their visit one to be remembered. Following registration on Monday morning, shopping time has been allowed until mid-afternoon, when a Get-Acquainted Tea Party will be held at the Women's City Club through the courtesy of the New England Sewage Works Association.

A motor tour of historic Boston and Charlestown on Tuesday morning will provide an opportunity to visit the many Revolutionary and pre-Revolutionary shrines of the area. In the afternoon, a guided tour of the Boston Museum has been arranged, with music in the Tapestry Room for those who prefer it.

On Wednesday, a special treat has been prepared in the form of a bus tour through the Cambridge-Lexington-Concord area, noted historically and beautiful in foliage at that time of the year. Luncheon during the tour will be at the Wayside Inn, South Sudbury, famous in story and song.

The Hancock Room has been reserved for the use of the ladies attending the convention and will serve as their headquarters.

INSPECTION TRIPS

Wednesday afternoon has been reserved for inspection trips to the Metropolitan District Commission's new Nut Island sewage treatment plant and to the new William T. Sedgwick laboratories of sanitary science at Masachusetts Institute of Technology. Group inspection of these modern sanitary facilities under the direction of well-informed guides will present an opportunity to relax with profit during this session of the technical program.

The Inspection Trip Committee will be prepared to assist those who may wish to visit any special points of technical interest near Boston. Time will be available Thursday afternoon for this purpose.

EXHIBITS

Rivaling the technical program in interest and variety, the display of sewage works equipment and supplies planned for the Twenty-Second Annual Meeting will be outstanding. All available exhibit space was allocated by the Water and Sewage Works Manufacturers' Association before mid-July. Twenty-nine

manufacturers and suppliers will display their products, and informed company representatives will supplement the exhibits of improved and new equipment with first-hand technical data.

The following companies will be represented in the exhibit:

American City Magazine
American Well Works
Builders-Providence, Inc.
Carter Company, Ralph B.
Chain Belt Company
Chicago Pump Company
Cloroben Corporation
Dorr Company, Inc.
Engineering News-Record
Flexible Sewer-Rod Equipment Company
Hardinge Company
Infilco, Inc.
Jeffrey Manufacturing Company
Johns-Manville Corporation
Link-Belt Company
Lock Joint Pipe Company
Pacific Flush-Tank Company
Preload Companies
Public Works Magazine
Sewage Works Engineering
Simplex Valve & Meter Company
Vapor Recovery Systems Company
Walker Process Equipment, Inc.
Wallace & Tiernan Company, Inc.
Warren Pipe Company of Massachusetts, Inc.
Water & Sewage Works
Westinghouse Electric Corp.
Worthington Pump & Machinery Corp.
Yeomans Brothers Company

REGISTRATION INFORMATION

A fee of $10.00 will cover registration, technical session privileges, the Monday Reception-Entertainment, and the Wednesday Dinner and Dance. For the ladies, the same fee will include all special ladies' entertainment events, as well as the Reception and the Annual Dinner and Dance. Tickets for the Annual Federation Luncheon on Tuesday will be $3.00, and for the Wednesday Inspection Trip will be $1.00. Separate tickets for the various events will be: registration fee (required for attendance at the technical sessions) $4.00; Reception-Entertainment $1.00; and Dinner and Dance $6.00.

HOTEL ACCOMMODATIONS

Ample hotel accommodations have been arranged for Federation members and guests attending the Boston meeting. However, reservations must be made well in advance, as Boston is a crowded tourist city during the fall months and rooms allocated for those attending the Federation meeting will probably be released to the general public about October 3.

Requests for reservations should be sent directly to the Hotel Statler, headquarters hotel for the convention. A schedule of room rates is indicated on the reservation request card that has been sent to all Federation members.

LOCAL ARRANGEMENTS COMMITTEE

The local arrangements committee, under the chairmanship of E. Sherman Chase, is composed of the chairmen of the following sub-committees:

Registration Committee: Kenneth I. Wilson, chairman; Worthem Taylor; E. W. Moore; Forrest Harbour.

Finance Committee: Thomas A. Berrigan, chairman; Stewart Newland; George C. Bogren; George C. Houser; Paul F. Howard.

Hotel Arrangements Committee: Edwin B. Cobb, chairman; A. A. Thomas; David M. Misner; Edmund H. Brown; John B. Nesbitt; William R. Clary.

Ladies Entertainment Committee: Mrs. Thomas A. Berrigan, chairman; Mrs. Thomas A. Camp; Mrs. E. Sherman Chase; Mrs. Edwin B. Cobb; Mrs. Stuart E. Coburn; Mrs. Frank L. Flood; Mrs. Joseph B. Hanlon; Mrs. Clair N. Sawyer; Mrs. Walter E. Merrill; Mrs. Gordon M. Fair; Mrs. A. Edward Sulesky; Mrs. Walter H. Brown; Mrs. LeRoy W. Van Kleeck.

Inspection Trips Committee: Robert W. Moir, chairman; George W. Coffin; Truman H. Safford; Adam E. Sulesky; Ralph M. Soule; Francis T. Bergin.

Transportation Committee: Ralph W. Horne, chairman; Harry P. Burden; Stanley M. Dore; C. Frederick Joy; C. S. Mansfield.

Local Host Committee: Charles G. Hammann, chairman; Charles O. Baird, Jr.; Eugene L. Bond; John H. Brooks, Jr.; E. S. Brown, Jr.; S. E. Coburn; George H. Craemer; William H. Daggett; J. Henry L. Giles; Paul C. Hedenstad; Harry E. Loftus; John D. McDonald; Seymour J. Ryckman; Walter J. Shea; William E. Stanley; Edward L. Tracy; William S. Wise.

Entertainment Committee: Clair N. Sawyer, chairman; William P. Brenchick; John S. Bethel; Fozi M. Cahaly; William H. Eastburn; F. H. Gibbs.

LATE NEWS SPECIAL

A last-minute addition to the Wednesday afternoon inspection trip program is a visit to an ingenious waste treatment plant handling fatty acids and soaps from waste soap manufacturing waters at the Proctor and Gamble Company's Quincy, Mass., plant. The units utilize controlled pH and finely divided air to float out the suspensions and floc formations for recovery and reprocessing, thus keeping them from clogging sewers and interfering with sewage treatment processes.

Reviews and Abstracts*

Aeration Speeds Grit Removal. By N. Grant. *Engineering News-Record*, **142**, 17, 57 (Apr. 28, 1949).

This describes an aerated grit chamber at Columbus, Ohio, on a combined sewer system. The grit removal structure is connected to the intercepting sewer by a 10.5 × 6.5-ft. conduit 130 ft. long, over which is a surge chamber. Two screen channels with mechanically cleaned screens (with 1-in. clear openings) distribute the flow to four uncovered tanks, each 43.75 by 19.75 ft., with 13-ft. water depth. Each tank includes four aeration units, with air diffusion through banks of five metallic tubes wound with chemically resistant cord, which create a spiral flow. The floor slopes to hoppers, from which the grit is removed by a clam-shell bucket (½ cu. yd.) carried by a traveling crane. With four tanks in operation, the data are:

Flow (m.g.d.)	Velocity (f.p.m.)	Detention Period (min.)
80	8	5
160	16	2.5

The clam-shell bucket empties into motor trucks. A control and service building covers the screen chamber. It is claimed that the aerated grit removal system has advantages in lower first cost, better separation of grit, uniformly clean grit, velocity of roll adjustable to flow, and addition of dissolved oxygen to the sewage.

Langdon Pearse

Interim Report to the International Joint Commission. By the Board of Technical Advisers re Pollution of International Boundry Waters. 28 pp. mimeo. (March, 1949).

This is an investigation of pollution, by sewage and industrial wastes, in the international boundary waters of the St. Clair River, Lake St. Clair, and the Detroit River; also, the St. Mary's River. The technical advisers were L. M. Fisher (vice J. K. Hoskins), M. LeBosquet, Jr., J. M. Helper, and L. F. Oeming for the United States; and G. H. Ferguson, W. R. Edmonds, A. E. Berry, and A. V. DelaPorte for Canada. A large number of samples was collected in 1946 and 1947, with investigation of 47 major industrial plants in the United States and 20 in Canada, pollution by navigation, and water quality. The present study covers practically the same area as in 1913.

The waters are extensively used for a variety of purposes. Since 1913, industrial wastes have become a major problem. About 90 per cent of the population is found in the United States. Partial treatment for 2,260,000 population (out of 2,385,000) is found in the United States, and complete treatment for 7,000 (out of 204,600) in Canada. The increase in sewage pollution has augmented the potential hazard to domestic water supply, and damages recreational uses and fish and wild life. In the United States, some corrective measures are under way. In Canada, but little has been done.

Pollution by navigation has become a major hazard.

Industrial wastes have increased in variety and volume, amounting, in the United States, to 1,204 m.g.d.; in Canada, to 374 m.g.d. Among the more significant wastes are phenol and phenolic equivalents, as 0.1 p.p.m. of phenol imparts taste and odor, and 0.002 p.p.m. in chlorinated water causes objectionable tastes and odors. Phenol tends to taint fish flesh and kill the fish.

Cyanides are very toxic. Concentrations of 0.1 to 0.3 p.p.m. are reported to kill fish. In the United States, 3,470 lb. per day enter the waters, as against 5 lb. per day in Canada.

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage Works Assns., 325 Illinois Bldg., Champaign, Ill.

Ammonium compounds cause fluctuations in chlorine demand. The toxicity to fish is regulated by pH concentration and death may occur in 10 days or less with 2.5 p.p.m. of ammonia, with pH 7.4 to 8.0. In the St. Clair and Detroit Rivers and Lake St. Clair, the United States produces 12,190 lb. per day; Canada, 560 lb. per day. In the St. Mary's River, Canada produces 48,020 lb. per day, the U. S. none.

Oils and ether soluble materials are also found—in the United States, 16,280 g.p.d.; in Canada, 4,010 g.p.d.

B.O.D. became important in the River Rouge and River Thames, where anaerobic nuisance occurred. For the St. Clair and Detroit Rivers and Lake St. Clair, the B.O.D. of industrial wastes was found to be 306,600 lb. per day in the United States and 114,600 lb. per day in Canada. On the St. Mary's River, the B.O.D. in the United States was 7,800 lb. per day; in Canada, 223,500 lb. per day.

The suspended solids discharged by industry totaled 1,707,400 lb. per day in the United States, and 668,300 lb. per day in Canada.

In 1913, the major source of pollution was domestic sewage. In 1948, oxygen depleting pollution, when adequately diffused, was not a major problem.

B. coli results differ widely with the location.

Industrial wastes are the chief source of chemical pollution, but are not evenly distributed. A substantial number of samples shows phenol concentrations in excess of 0.01 p.p.m., with occasional samples as high as 0.40 p.p.m. Oil is present on many bathing beaches. Complaints have arisen from tastes and odors, due to industrial wastes.

Float tests indicate that in certain areas pollution travels from either side of the boundary to the other.

The hearings of the Commission (12 days) developed that pollution from both industrial wastes and domestic sewage in 1945 created complaints in both countries, affected municipal water supplies, and injured fish, wild fowl, and aquatic life. The industries are working to treat their wastes. Municipalities are studying extension of facilities, but are relatively inactive in construction because of financial problems. The pollution has interfered with the recreational use of the waters.

Regional planning is indicated as helpful.

The estimated costs of remedial measures are:

	Municipal	Industrial
United States	$68,000,000	$13,000,000
Canada	14,000,000	3,000,000
Total	$82,000,000	$16,000,000

The advisory board recommended that the Commission maintain contact with the pollution control problem, formulate a program, and work for the cooperation of all agencies concerned.

LANGDON PEARSE

Building Drainage. By F. L. Barrow. *Journal of the Institution of Sanitary Engineers*, **Vol. 48**, Part 2, pp. 115–136 (April, 1949).

This is a general summary of British practice in building drainage (with occasional reference to American practice) on pipe sizes, gradients, changes in direction, concrete support of tile pipes, trapping, and ventilation. Access through buried rodding eyes or manholes is desirable.

The discussion covered various points. E. H. Vick urged that manholes should be large enough for efficient use and that branch drains should not make turns of more than 90 degrees. Weston pointed out the difficulty of opening bolted covers on access specials. Temple stated that he could pass through a 15-in. ring. Finch urged the use of 5-in. instead of 6-in. house connections and objected to buried access rodding eyes. Trusler advocated 3-in. soil pipe and 3-in. drain. Carter indicated that 5-in. tile were of doubtful economic value. B. Hamburger noted that interceptor traps kept rats from moving in the drain (!) and urged complete records of sewers and manholes. Pipe sizes can be standardized. Berry notes the use of 4- to 24-in. vitrified tile, particularly 4-, 6-, 9-, and 12-in. Odd sizes (5-, 7-,8 -, and 10-in.) are not common practice. Berry admitted that the use of 5-in. drains is negligible.

York urged accessibility for cleaning and a minimum of traps on house drains. S. F. Morris concurred in avoiding changes of direction greater than 45 deg., except at manholes, objected to intercepting traps, and urged frequent manholes. [Ab-

stractor's Note—As American practice is generally covered by municipal ordinance, this paper has little value to American engineers.]

LANGDON PEARSE

Report, Melbourne and Metropolitan Board of Works (Australia), for Year Ended June 30, 1948.

The Board is planning for an estimated future population of 2,000,000 in the year 2000. (The population of Melbourne in 1947 was 1,226,933, from the "Information Please Almanac," 1949).

The sewerage system was designed primarily for domestic sewage, but industrial wastes now account for 22.5 per cent of the normal week-day dry flow and of the cost of collection and disposal. In 1945 the Sewerage Committee recommended a charge for such service, and in 1946 obtained legislation authorizing agreements with industrial establishments. Under a By-law, in 1949 charges are levied in addition to the normal rates of 10 sh. ($1.61) for each 10,000 Imp. (12,000 U. S.) gal. of waste, with a minimum annual charge of £5 ($16.14). Industries are encouraged to spread their discharge by a discount of 2.5 per cent for every 5 per cent by which the ratio of maximum hourly discharge to mean hourly discharge is less than 4 to 1, provided that in no case shall the discount exceed 30 per cent. In view of the difficulty of installing sewage meters, the levy is based on the water supplied, the trade waste quantity to be determined either by multiplying the quantity of water supplied by a factor to be fixed for each case, or by deducting from the total quantity of water supplied the quantity not discharged to the sewer as trade waste. These charges do not apply to domestic sewage. The By-law provides that where both domestic sewage and industrial waste discharge through a common outlet, the domestic sewage be calculated at the rate of 30,000 Imp. (36,000 U. S.) gal. per year per water closet.

The sewage is treated at the Metropolitan Farm, comprising 24,610 acres, 24 mi. southwest of Melbourne. This receives over 99 per cent of the sewage flow. Systematic grazing is practiced. The net annual cost of purification and disposal is only 2*s*. 3*d*. (36.3¢) per capita. The net cost of operation of the farm was £133,291 ($430,000) during the year, after selling 4,657 cattle for a return of £88,549 ($286,000). On June 30, 1948, there were 13,237 cattle on the farm.

LANGDON PEARSE

Treatment of Waste Waters from Agricultural Industries. By B. A. SOUTHGATE. Congres Internationale Des Industries Agricoles, Paris, pp. 1–18, 1948.

Urine not absorbed by the straw in cow sheds is drained into a tank, carted away, and used as liquid manure. Floor washings from the barn are diverted to another drain and are sometimes treated by sedimentation before being applied on land, or may be treated by trickling filters. Washings may have a B.O.D. of 450 p.p.m.

At dairies where milk is received, pasteurized, and bottled, the loss of milk from floor washings should be about 0.5 per cent of the volume of milk handled; where special precautions are taken the milk loss could be reduced to 0.2 per cent.

In cheese factories the whey produced has a B.O.D. of 40,000 p.p.m. and should never be discharged to a stream. In Great Britian it is fed to farm animals or used in the preparation of foodstuffs. Similarly, skim milk and buttermilk should not be discharged and their losses should be reduced to a minimum.

Wastes containing milk and milk products have been treated by anaerobic digestion, but the process produces offensive odors and the effluent is unsuitable for discharge to a stream. The activated sludge process also has been used in various places, but the final effluents produced have not always been of very good quality.

The experimental work dealing with the treatment of milk washings and milk products by alternating double filtration, conducted by Water Pollution Research Laboratory in England, is reviewed. The thick film growth on the first filter of the series was dispersed by the alternation.

Chemical treatment brings about 50 per cent reduction of B.O.D. Reduction may be increased to 80 per cent by careful control, but to achieve this comparatively large amounts of coagulant are required.

Wastes produced from canning and drying of vegetables and fruits fluctuate widely in volume and composition during the year. Screens are advocated for removing part of the solids. Lagooning, with the addition of sodium nitrate, has

been practiced for cannery wastes in America. Sedimentation removes a large proportion of the suspended matter, but not of the B.O.D. The solids recovered undergo fermentation and rise to the surface of the tanks. After sedimentation the liquors can be treated satisfactorily by trickling filters.

The weight of polluting matter discharged from slaughtering of animals varies widely and depends largely on the extent to which by-products are recovered. At some plants blood, fats, and offal are removed and utilized. The liquors should first be put through screens and sedimentation tanks. They may then be treated by trickling filters. Recirculation of effluent helps to dilute the waste and results in improvement. Wastes have also been treated by the activated sludge process, but a good deal of difficulty is encountered.

The various wastes produced from the manufacture of beet sugar are best dealt with by reusing them in the factory processes after suitable pretreatment. Water from fluming and washing are passed through lagoons or sedimentation tanks, and reused for the same purpose. The liquid drained and pressed from spent pulp is 400 gal. per ton of beet, contains sugars, and has a B.O.D. of 1,000 to 1,500 p.p.m. Lime treatment gives a B.O.D. reduction of 50 per cent; trickling filters, 80 per cent. Because of the expense involved in treating this waste by trickling filters, the liquor is screened and returned to diffusion batteries. The condenser water can be cooled and reused. When all three liquors are used, the polluting material discharged during a season can be reduced greatly. At the end of the season the waste may be discharged, with or without treatment, slowly into the stream.

Wastes produced from steeping of barley have a B.O.D. of at least 500 p.p.m., and have been treated successfully by trickling filters. Waste waters from brewing consist mainly of wash waters. The volume of waste is about 9 to 11 gal. per gallon of beer brewed. Brewery wastes have been treated by trickling filters without admixture with sewage, and by the activated sludge process.

Waste waters from the manufacture of alcohol have a B.O.D. of 15,000 to 30,000, p.p.m. Waste waters from distilleries have been reused, fed to animals, or treated by digestion, with or without subsequent biological filtration.

Most of the flax in Great Britain is retted at factores instead of by the old method of retting in the streams. The retting was being done under anaerobic conditions and the liquors, which were acidic and had a high B.O.D. color, and odor, were discharged into the stream. Experimental work done by the Water Pollution Research Laboratory showed that the liquor could be treated by trickling filters, but because of the seasonal nature of the industry the method of retting was changed from anaerobic to an aerobic process, from which no waste water need be discharged. The liquor in the retting tank is aerated, whereby the amount of acidic materials is reduced and the liquor can be reused continuously throughout a retting season. The fiber produced from the aerated process has been as suitable as that produced from the anaerobic retting.

H. HEUKELEKIAN

Preliminary Studies on the Viability and Dispersal of Coliform Bacteria in the Sea. By BOSTWICK H. KETCHUM, CORNELIA L. CAREY, AND MARGARET BRIGGS. *Contribution No.* 446, Woods Hole Oceanographic Institution, Woods Hole, Mass. (1949).

Previous investigations of the death rate of *Escherichia coli* in sea water have given divergent results varying from death rates much more rapid than are found in fresh waters to the conclusion that sea water is neither antiseptic nor inimical to enteric bacteria.

When natural unpolluted sea water is brought to the laboratory a tremendous growth of bacterial population takes place on storage. The numbers thereafter decrease to a more or less uniform level of about 1,000,000 cells per ml. A slight increase in bacterial numbers is also detected in water to which coliforms are added artificially. This is followed by a decrease, so that the final populations are approximately the same whether *E. coli* is added or not. *E. coli*, on the other hand, decrease rapidly. Thus, the final populations in both raw sea water and in water inoculated with *E. coli* consist of normal sea water organisms. If *E. coli* is introduced to autoclaved sea water the death rate is very slow. In boiled sea water the

death rate is more rapid and is similar to the rate found in untreated sea water, indicating that the bactericidal action of sea water is destroyed by autoclaving, but is unaffected by milder boiling treatment. If, after the disappearance of the coliform organisms, another similar inoculum is added, the death rate is more rapid than that of the first inoculum. Thus, previous pollution increases the death rate.

It is suggested that antibiotic substances produced by marine organisms may be responsible for the death of the pollution bacteria. Other possibilities, such as bacteriophage or autolytic products of the coliforms themselves, may be involved.

Studies were made at New Bedford, Mass., where sewage is introducted from an outfall 1,100 yd. off shore at 30-ft. depth. The surface distribution of salinity and bacteria along the axis and across the axis of the tidal current was determined. The introduced sewage is diluted with 13 to 14 volumes of sea water by the time it appears at the surface. In crossing the axis of the current in the neighborhood of the outfall, the bacterial numbers increase, and then decrease on the other side. The distribution of salinity and of bacteria along the axis are similar, except that the downstream distances required to reach a given concentration are greater. The bacterial numbers are, however, always lower than would be predicted on the basis of dilution alone.

H. Heukelekian

Waste Disposal Featured at Refining Meeting. Anonymous. *Chemical and Engineering News*, **27**, 17, 1211 (Apr. 25, 1949).

Waste disposal problems of the refining industry were discussed at a recent meeting of the American Petroleum Institute. The problems have increased in significance during the 20 years since the organization of the A.P.I. committee on waste disposal, and the oil refining industry is doing a concentrated, organized job of cooperating with various agencies and others involved in combating stream pollution.

Methods for the biological measurement of stream conditions were discussed in detail at the meeting. The effect of by-products and spent chemicals on surface waters, and procedures and equipment for disposal of the most common types of refining chemicals, were reviewed, as was the subject of refinery effluent conditioning for reuse and disposal.

A separator designed according to A.P.I. criteria and capable of handling 500 g.p.m. of process water with 95 per cent oil recovery was also described.

Paul D. Haney

Microbiological Problems in the Manufacture of Sugar from Beet. Part II. Losses Due to Fermentation During the Diffusion Process. By L. A. Allen, A. H. Cooper, and M. C. C. Maxwell. *Journal of the Society of Chemical Industry* (England) **67**, pp. 450–457 (1948).

Part I of the subject paper (abstracted in This Journal, **21**, 3, 594; May, 1949) described an investigation, undertaken at the request of the British Sugar Corporation, of the factors responsible for corrosion in a beet sugar diffusion battery employing recirculation. The study covered the isolation of micro-organisms producing acidity, the measurement of corrosion occurring in different parts of the battery, and the effectiveness of chlorination and of other remedial measures in checking acidity and in reducing corrosion. Part II describes an investigation of chemical changes and of gas production caused by bacterial and biological activity in the diffusion batteries in which process waters are reused.

Observations in the factory—including investigations of temperatures of juice entering and within respective battery cells; analyses of gas in the several cells of two batteries; chemical examination of samples of juice from various steps of diffusion, and of battery supply water; and studies of bacterial flora of samples from the diffusion systems—paralleled by laboratory studies of chemical changes produced by plant operation and by bacterial flora, suggest certain conclusions as follows:

1. In the process of diffusion, gas collecting at the top of cells in series contains a decreasing amount of carbon dioxide toward the extraction end of the battery.

2. Observations on the respiration of freshly sliced beets indicate that this factor is probably largely responsible for the carbon dioxide at the beginning of diffusion, but that rising temperature of

juice in the battery inhibits further plant respiration and that periodic opening of battery cell release cocks, a usual phase of operation, tends to replace the original gases by those released from the juice.

3. The latter include products of fermentation comprising carbon dioxide and hydrogen.

4. Thermophilic flora of the diffusing juice consist mainly of lactobacilli and gas-forming anaerobes, which apparently are responsible for the production of gas, the formation of invert sugar, and the appearance in the juice of small amounts of lactic, butyric, and acetic acids.

5. The effect of temperature changes on the prevalent micro-organisms as conducted in the laboratory indicates they will be inhibited if the temperature of the battery were constantly maintained above 70° C.

BRUCE M. MCDILL

New Technique for Waste Pickle Liquor Neutralization. By RICHARD D. HOAK AND CHARLES J. SINDLINGER. *Industrial and Engineering Chemistry*, **41**, 65–70 (Jan., 1949).

Investigation of waste pickle liquor neutralization has led to the development of a process whereby a sludge can be produced which settles to a much smaller final volume than can be attained by conventional methods. The settling rate of the slurry made by this process is high and the filtration rate is much higher than that of conventional slurries.

The fundamental principle on which the new process operates is the controlled oxidation of the ferrous hydrate to ferrous-ferric oxide. Alkaline agents used in this investigation were magnesia, high-calcium quicklime, and dolomitic quicklime. Basically, the process described consists of feeding pickle liquor at a uniform rate into a reactor containing the neutralizing agent plus previously precipitated slurry, where the temperature is maintained at 75° C. and efficient aeration is provided. The amount of air required for oxidation is based on the reaction $3FeO + \frac{1}{2}O_2 \rightarrow FeO \cdot Fe_2O_3$. The theoretical air requirement for a ferric to ferrous iron ratio of 2.25 is 0.772 cu. ft. of air (measured at 20° C. and 1 atmosphere) per liter of pickle liquor converted. The actual amount of air required will exceed the theoretical under all practical conditions, because of incomplete oxygen absorption. Where oxidation rate controls, as in the case when high-calcium lime is used as the pickle liquor treating agent, it is advantageous to use a high rate of air feed at low oxygen efficiency. Where neutralization rate controls, as in the case of the use of dolomitic lime, it is desirable to restrain oxidation by using a low air feed rate. This results in a higher oxygen efficiency.

A decision as to the best neutralizing agent to use will depend largely on economic factors. Magnesia can be used where recovery of iron oxide and magnesium sulfate is economically sound. High-calcium lime yields a slurry that filters quite readily. Dolomitic lime falls between magnesia and high-calcium lime in final sludge volume.

Operation of the process on a continuous basis can be accomplished readily by installing constant-rate, alkaline-agent, feeding equipment. For optimum results the supernatant liquor should contain little or no soluble iron, the ferric to ferrous iron ratio should be 2.5 to 3.5 (but may be in the range from 2 to 5), and the reaction temperature should be above 80° C.

It is tentatively concluded that a reaction tank 7 ft. in diameter by 20 ft. high would handle 10,000 gal. of strong pickle liquor per 8-hr. day.

The work described in this paper was conducted at the Mellon Institute, Pittsburgh, Pa., as a part of the research program of the Stream Pollution Committee of the American Iron and Steel Institute.

PAUL D. HANEY

The Position of Industry in Stream Sanitation. By RUSSELL L. WINGET. *Proceedings, First Annual Public Health Engineering Conference*, 1948. Civil Engineering Section, Engineering and Industrial Experiment Station, University of Florida, Gainesville, Fla.

Dissimilarities in the nature of industrial and municipal waste pollution problems are pointed out to be: (1) most industrial wastes such as those from the pulp and paper industry are not a health menace or a bacterial pollution problem; (2) municipal sewage waste treatment procedures are well developed and equipment is readily available, whereas individual industrial waste treatment processes and facilities have to be developed in the laboratory and laboriously adopted to

full-scale treatment works; and (3) industrial waste treatment cannot be financed by public funds, but must be paid for with operating funds from a business that is almost invariably highly competitive.

The relatively low pollutional effect of the Florida pulp and paper wastes is emphasized and the need is pointed out for considering the $200,000,000 investment of the industry in Florida, as well as the third-place position of the value of its products in balancing the industry's and the people's rights to the use of the waters of the state.

M. R. Golly

Disposal of Citrus Cannery Wastes. By Robert McNary. *Proceedings, First Annual Public Health Engineering Conference,* 1948. Civil Engineering Section, Engineering and Industrial Experiment Station, University of Florida, Gainesville, Fla.

The citrus industry contributes pollution to central Florida waters largely from 67 canning plants and 18 citrus feed mills.

At the present time the concentrated wastes, consisting of peel, rag, and seeds, are generally converted to cattle feed and citrus molasses. Prevailing economic conditions determine whether or not recovery of these wastes is profitable. Stream pollution caused by the industry in most cases is the result of discharge of wash water and drippings too dilute for evaporation to molasses, but too strong for treatment by conventional sewage treatment methods. Lagooning and sub-surface seepage have been used with varying degrees of success, but biological filter treatment costs have been found exorbitant. Research, by the Florida Citrus Commission, with an anaerobic fermentation process has showed promising results and pilot plant studies have been started.

M. R. Golly

The Position of the Pebble Phosphate Industry in Stream Sanitation. By R. B. Fuller. *Proceedings, First Annual Public Health Engineering Conference,* 1948. Civil Engineering Section, Engineering and Industrial Experiment Station, University of Florida, Gainesville, Fla.

The possibility of the phosphate industry adversely affecting streams did not arise until about 20 years ago, when the flotation process was perfected for increasing the recovery of pebble phosphate. A modern phosphate mine requires about 30,000 g.p.m. of clear water, and large areas for clear-water reservoirs, slime-settling basins, and tailings sand storage. With these facilities, discharge of wastes can be largely prevented, except during periods when heavy rainfall overtaxes storage capacity.

Research carried on at the University of Florida and sponsored by the phosphate industry has produced the following information:

1. Removal of semicolloidal matter in the settling areas is one of the chief difficulties.

2. The results of dissolved oxygen and biochemical oxygen surveys have shown that streams were actually improved in this respect by the effluents from phosphate operations.

3. Detrimental effect on fish has not been found, but the possibility of destruction of fish food has been suggested.

4. Although water in the Red Tide areas off Florida's west coast contain 2 to 10 times the normal phosphorus concentration, there is no evidence that the phosphate industry is responsible.

M. R. Golly

Soils Pollution in the Potomac River Basin. By Harold A. Kemp. Interstate Commission on the Potomac River Basin, Washington, D. C. 21 pp.

Stream pollution by sanitary sewage and industrial wastes has been the concern of the Commission during its first phase of cleaning up the Potomac River basin. Now, however, it is concerning itself also with the third type of pollution—that of soil erosion—whose adverse effects have been greater in some cases than damage caused by either of the other types.

In 1948 the mud load of the Potomac River at Washington was 1,650,000 tons, as computed from turbidity tests, in addition to an estimated 200,000 tons of sand and gravel in the river's bed load. The 30,000,000 cu. ft. of soil lost annually above Washington is not due to stream bed erosion, but to top soil erosion.

Besides their adverse effect on fish and aquatic plant life, the turbid waters cause considerable expenditures for domestic supply filtration, industrial supply treatment, and navigational dredging. In

addition, the silt represents capital loss to the agricultural interests of the basin. Reduction of the river's turbidity to less than 100 p.p.m. would annually save, for Washington alone, about $34,000 in treatment chemicals, $12,000 in reservoir dredging costs, and $5,000 in cleaning of filters. In addition, an estimated $60,000 per year would be saved in navigational dredging from the mouth to the head of navigation (at Washington). Adequate soil conservation methods throughout the basin are expected to reduce the flood peak stages by 1 ft. at Washington, and by 3 ft. or more in the upstream reaches. Costly cleanup operations in the removal of mud and debris would be considerably reduced.

H. P. Orland

Financing Sewerage Works. Second Edition. Portland Cement Association, Chicago, Ill. 24 pp. (1948).

An excellent summary is given of the factors affecting state and municipal legislation pertaining to public improvement financing. The various kinds of financing available are thoroughly discussed, and outlines are given for a model revenue bond ordinance and a model rate ordinance. Suggestions on educational campaigns for financing the improvement are also given, in addition to hints on billing and collection, with model forms. A list of 13 excellent references is included, together with a table of state provisions relating to water and sewer districts, as reported by state authorities.

H. P. Orland

Synthetic Detergents Present Sewage Problem. *Chemical and Engineering News*, **27**, 24, 1723 (June 13, 1949).

Apparently synthetic detergents cause serious operating problems at both sewage and water treatment plants. These problems were discussed at the Chicago meeting of the American Water Works Association (May 30-June 3, 1949). Sewage plant operators have noted that within the last year the efficiency of settling tanks declined on "wash" days. During the past winter, water treatment plants receiving substantial amounts of sewage from upstream communities experienced difficulty with the sedimentation of alum-coagulated water.

The proof that synthetic detergents are responsible for these difficulties is not positive, however, as there is no known analytical technique for detecting very low concentrations of these substances. Existing analytical procedures give questionable results at 200-p.p.m. concentrations. The exact concentration at which water and sewage treatment difficulties occur has not been determined, but it is undoubtedly quite low. Work on tannates and sulfite wastes indicates that these wastes affect coagulation adversely at concentrations of the order of 1 p.p.m. Tests conducted at Chicago have indicated that trouble from synthetic detergents generally could be expected at concentrations greater than 5 p.p.m. Household types have greater inhibiting action than industrial agents.

The immediate problems are to develop analytical methods and to find means of counteracting the persistent dispersing power of the synthetic detergents.

Paul D. Haney

Directory of Equipment and Supplies Used in Industrial Waste and Sewage Works

The Buyer's Directory of industrial waste and sewage works equipment and supplies presented here is an innovation to SEWAGE WORKS JOURNAL. It will be carried only as a feature of each Annual Convention Number.

The Directory will be a particularly valuable reference for consulting engineers, industrial engineers, municipal engineers, and sewage works administrative and operation personnel. All of the companies represented are supporters of the Federation as JOURNAL advertisers.

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Norton Co., Worcester 6, Mass.

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American Well Works, 100 N. Broadway, Aurora, Ill.
Walker Process Equipment, Inc., Aurora, Ill.

Aerators, Mechanical

American Well Works, 100 N. Broadway, Aurora, Ill.
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.
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Yeomans Brothers Co., 1411 N. Dayton St., Chicago 22, Ill.

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Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
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Jeffrey Manufacturing Co., 902 N. Fourth St., Columbus 16, Ohio
Wallace & Tiernan Co., Inc., Newark 1, N. J.

CHEMICAL PRECIPITATION PROCESSES

Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.

CHEMICALS

Alum

General Chemical Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.

Ammonia

General Chemical Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.

Ammonia Alum

General Chemical Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.

Cloroben

Cloroben Corp., 15 Exchange Pl., Jersey City 2, N. J.

Sodium Silicate

General Chemical Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.

Sulfuric Acid

General Chemical Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.

Trisodium Phosphate

General Chemical Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.

CHLORINATION EQUIPMENT

Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Manufacturing Corp., 207 W. Huron St., Chicago 10, Ill.
Wallace & Tiernan Co., Inc., Newark, N. J.

CLARIFIER EQUIPMENT

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.
Jeffrey Manufacturing Co., 902 N. Fourth St., Columbus 16, Ohio
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Walker Process Equipment, Inc., Aurora, Ill.
Yeomans Brothers Co., 1411 N. Dayton St., Chicago 22, Ill.

CLOROBEN

Cloroben Corp., 15 Exchange Pl., Jersey City 2, N. J.

COAGULATION EQUIPMENT

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.
Jeffrey Manufacturing Co., 902 N. Fourth St., Columbus 16, Ohio
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Walker Process Equipment, Inc., Aurora, Ill.

COATINGS, PROTECTIVE

Inertol Co., Inc., 470 Frelinghuysen Ave., Newark 5, N. J.
Koppers Co., Inc., Pittsburgh 19, Pa.

COCKS, LUBRICATED PLUG

American Car and Foundry Co., 30 Church St., New York 8, N. Y.

COLLECTORS, SLUDGE AND GRIT

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.
Jeffrey Manufacturing Co., 902 N. Fourth St., Columbus 16, Ohio
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Walker Process Equipment, Inc., Aurora, Ill.
Yeomans Brothers Co., 1411 N. Dayton St., Chicago 22, Ill.

COMBUSTION INDICATORS AND RECORDERS

Bailey Meter Co., 1066 Ivanhoe Rd., Cleveland 10, Ohio
Brown Instrument Div., Minneapolis-Honeywell Regulator Co., 4518 Wayne Ave., Philadelphia 44, Pa.

COMMINUTION EQUIPMENT

Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.

COMPARATORS, pH AND RESIDUAL CHLORINE

Wallace & Tiernan Co., Inc., Newark 1, N. J.

COMPRESSORS, AIR

Yeomans Brothers Co., 1411 N. Dayton St., Chicago 22, Ill.

CONCRETE PIPE

Portland Cement Association, 33 W. Grand Ave., Chicago 10, Ill.

CONTROLLERS, FLOW, PRESSURE, TEMPERATURE, VACUUM

Bailey Meter Co., 1066 Ivanhoe Rd., Cleveland 10, Ohio
Brown Instrument Div., Minneapolis-Honeywell Regulator Co., 4518 Wayne Ave., Philadelphia 44, Pa.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.
Simplex Valve & Meter Co., 6719 Upland St., Philadelphia 42, Pa.

CONVEYING EQUIPMENT

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.

Hardinge Co., Inc., 240 Arch St., York, Pa.
Jeffrey Manufacturing Co., 902 N. Fourth St., Columbus 16, Ohio
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Walker Process Equipment, Inc., Aurora, Ill.

COPPER PRODUCTS

American Brass Co., Waterbury 88, Conn.

CORROSION CONTROL

Electro Rust-Proofing Corp., Belleville 9, N. J.
Inertol Co., Inc., 470 Frelinghuysen Ave., Newark 5, N. J.
Koppers Co., Inc., Pittsburgh 19, Pa.

CUTTERS, ROOT

Flexible Sewer Rod Equipment Co., 9059 Venice Blvd., Los Angeles 34, Calif.
W. H. Stewart, Inc., P. O. Box 767, Syracuse, N. Y.

DEWATERING EQUIPMENT, SLUDGE

Eimco Corporation, Salt Lake City, Utah
General American Transportation Corp., 10 E. 49th St., New York 17, N. Y.

DIFFUSION EQUIPMENT

Jet Diffusers

American Well Works, 100 N. Broadway, Aurora, Ill.
Walker Process Equipment, Inc., Aurora, Ill.

Porous Plates and Tubes

Carborundum Co., Refractories Div., Perth Amboy, N. J.
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Norton Co., Worcester 6, Mass.

Diffuser Holders

Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.

DIGESTER EQUIPMENT

Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Hardinge Co., Inc. 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
Walker Process Equipment, Inc., Aurora, Ill.
Yeomans Brothers Co., 1411 N. Dayton St., Chicago 22, Ill.

DISINTEGRATORS, SLUDGE

Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Jeffrey Manufacturing Co., 902 N. Fourth St., Columbus 16, Ohio

DISTRIBUTORS, TRICKLING FILTER

American Well Works, 100 N. Broadway, Aurora, Ill.
Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Walker Process Equipment, Inc., Aurora, Ill.
Yeomans Brother Co., 1411 N. Dayton St., Chicago 22, Ill.

DRYERS, SLUDGE

Dorr Co., 570 Lexington Ave., New York 22, N. Y.
General American Transportation Corp., 10 E. 49 St., New York 17, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Nichols Engineering & Research Corp., 70 Pine St., New York 5, N. Y.

EJECTORS, SEWAGE

Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Yeomans Brothers Co., 1411 N. Dayton St., Chicago 22, Ill.

ELEVATORS, SLUDGE AND GRIT

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Jeffrey Manufacturing Co., 902 N. Fourth St., Columbus 16, Ohio
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Walker Process Equipment, Inc., Aurora, Ill.

FILTER-CLARIFIERS, SAND

Hardinge Co., Inc., 240 Arch St., York, Pa.

FILTERS, MAGNETITE

Magnetite Filter Corp., 10 E. 40 St., New York 16, N. Y.

FILTERS, SAND BACKWASH

Hardinge Co., Inc., 240 Arch St., York, Pa.

FILTERS, TRICKLING

Dosing Siphons

American Well Works, 100 N. Broadway, Aurora, Ill.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.

High-Rate Filters

Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Yeomans Brothers Co., 1411 N. Dayton St., Chicago 22, Ill.

Nozzles

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.

Rotary Distributors

American Well Works, 100 N. Broadway, Aurora, Ill.
Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Walker Process Equipment, Inc., Aurora, Ill.
Yeomans Brothers Co., 1411 N. Dayton St., Chicago 22, Ill.

Underdrain Blocks

Ayer-McCarel-Reagan Clay Co., Brazil, Ind.
Bowerston Shale Co., Bowerston, Ohio
Clay Products Association, 100 N. LaSalle St., Chicago 2, Ill.
W. S. Dickey Clay Manufacturing Co., Kansas City 6, Mo.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.
National Clay Pipe Manufacturers, Inc., 100 N. LaSalle St., Chicago 2, Ill.
National Fireproofing Corp., Pittsburgh 12, Pa.
Pomona Terra-Cotta Co., Pomona, N. C.
Texas Vitrified Pipe Co., Mineral Wells, Texas

FILTERS, VACUUM

Eimco Corporation, Salt Lake City, Utah
General American Transportation Corp., 10 E. 49 St., New York 17, N. Y.

FITTINGS, CAST IRON

American Cast Iron Pipe Co., Birmingham 2, Ala.
Cast Iron Pipe Research Association, 122 S. Michigan Ave., Chicago 3, Ill.
James B. Clow & Sons, 201–299 N. Talman Ave., Chicago 80, Ill.
U. S. Pipe and Foundry Co., Burlington, N. J.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia 5, Pa.

FLOCCULATION EQUIPMENT

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Avenue, New York 22, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.
Jeffrey Manufacturing Co., 902 N. Fourth St., Columbus 16, Ohio
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Walker Process Equipment, Inc., Aurora, Ill.

FLOOR STANDS

American Car and Foundry Co., 30 Church St., New York 8, N. Y.
James B. Clow & Sons, 201–299 N. Talman Ave., Chicago 80, Ill.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Oskaloosa, Iowa
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia 5, Pa.

FLOTATION EQUIPMENT, GREASE

American Well Works, 100 N. Broadway, Aurora, Ill.
Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.

FLUMES, MEASURING

Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 6719 Upland St., Philadelphia 42, Pa.

FLUSH TANKS, SEWER

Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.

GAS HOLDERS

Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Walker Process Equipment, Inc., Aurora, Ill.

GAS UTILIZATION APPURTENANCES

Brown Instrument Div., Minneapolis-Honeywell Regulator Co., 4518 Wayne Ave., Philadelphia 44, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Pittsburgh Equitable Meter Div., Rockwell Manufacturing Co., Pittsburgh 8, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

GASKETS, PIPE

James B. Clow & Sons, 201–299 N. Talman Ave., Chicago 80, Ill.
Johns-Manville Sales Corp., 22 E. 40 St., New York 16, N. Y.

GATES

Gates, Back Water

Armco Drainage & Metal Products, Inc., 2055 Curtis St., Middletown, Ohio

Gates, Shear

Armco Drainage & Metal Products, Inc., 2055 Curtis St., Middletown, Ohio
Chapman Valve Manufacturing Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Oskaloosa, Iowa

Gates, Sluice

Armco Drainage & Metal Products, Inc., 2055 Curtis St., Middletown, Ohio
Chapman Valve Manufacturing Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Oskaloosa, Iowa

GAUGES

Bailey Meter Company, 1050 Ivanhoe Road, Cleveland 10, Ohio
Brown Instrument Div., Minneapolis-Honeywell Regulator Co., 4518 Wayne Ave., Philadelphia 44, Pa.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 6719 Upland St., Philadelphia 42, Pa.

GRINDERS, GARBAGE AND SCREENINGS

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Gruendler Crusher & Pulverizer Co., 2929 N. Market St., St. Louis 6, Mo.
Jeffrey Manufacturing Co., 902 N. Fourth St., Columbus 16, Ohio

GRINDERS, SLUDGE

Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Jeffrey Manufacturing Co., 902 N. Fourth St., Columbus 16, Ohio

GRIT CHAMBER EQUIPMENT

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.
Jeffrey Manufacturing Co., 902 N. Fourth St., Columbus 16, Ohio
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Walker Process Equipment, Inc., Aurora, Ill.

HEAT EXCHANGERS, SLUDGE

Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Walker Process Equipment, Inc., Aurora, Ill.

HYDRANTS

Chapman Valve Manufacturing Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Oskaloosa, Iowa
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia 5, Pa.

HYPOCHLORINATORS

Everson Manufacturing Corp., 207 W. Huron St., Chicago 10, Ill.
Wallace & Tiernan Co., Inc., Newark 1, N. J.

INCINERATION EQUIPMENT

Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Nichols Engineering & Research Corp., 70 Pine St., New York 5, N. Y.

INSTRUMENTS, MEASURING, RECORDING

Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio
Brown Instrument Div., Minneapolis-Honeywell Regulator Co., 4518 Wayne Ave., Philadelphia 44, Pa.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.
Pittsburgh Equitable Meter Div., Rockwell Manufacturing Co., Pittsburgh 8, Pa.
Simplex Valve & Meter Co., 6719 Upland St., Philadelphia 42, Pa.

INSULATION

Johns-Manville Sales Corp., 22 E. 40 St., New York 16, N. Y.

JOINTING COMPOUNDS, SEWER

Clay Products Association, 100 N. LaSalle St., Chicago 2, Ill.
W. S. Dickey Clay Manufacturing Co., Kansas City 6, Mo.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.

LUBRICANTS, VALVE

American Car and Foundry Co., 30 Church St., New York 8, N. Y.
Nordstrom Valve Div., Rockwell Manufacturing Co., 400 N. Lexington Ave., Pittsburgh 16, Pa.

MANHOLE FRAMES AND COVERS

James B. Clow & Sons, 201-299 N. Talman, Chicago 80, Ill.

MANOMETERS

Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio
Brown Instrument Div., Minneapolis-Honeywell Regulator Co., 4518 Wayne Ave., Philadelphia 44, Pa.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.
Simplex Valve & Meter Co., 6719 Upland St., Philadelphia 42, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

METERS

Meters, Conveyor

Builders-Providence, Inc., 9 Codding St., Providence, R. I.

Meters, Flume

Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 6719 Upland St., Philadelphia 42, Pa.

Meters, Gas

Brown Instrument Div., Minneapolis-Honeywell Regulator Co., 4518 Wayne Ave., Philadelphia 44, Pa.
Nordstrom Valve Div., Rockwell Manufacturing Co., 400 N. Lexington Ave., Pittsburgh 16, Pa.
Simplex Valve & Meter Co., 6719 Upland St., Philadelphia 42, Pa.

Meters, Oil

Nordstrom Valve Div., Rockwell Manufacturing Co., 400 N. Lexington Ave., Pittsburgh 16, Pa.

Meters, Sludge

Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio
Brown Instrument Div., Minneapolis-Honeywell Regulator Co., 4518 Wayne Ave., Philadelphia 44, Pa.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 6719 Upland St., Philadelphia 42, Pa.

Meters, Water and Sewage

Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio
Brown Instrument Div., Minneapolis-Honeywell Regulator Co., 4518 Wayne Ave., Philadelphia 44, Pa.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Nordstrom Valve Div., Rockwell Manufacturing Co., 400 N. Lexington Ave., Pittsburgh 16, Pa.
Simplex Valve & Meter Co., 6719 Upland St., Philadelphia 42, Pa.

MIXING EQUIPMENT

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York 22, N. Y.
General American Transportation Corp., 10 E. 49 St., New York 17, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.
Jeffrey Manufacturing Co., 902 N. Fourth St., Columbus 16, Ohio
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Walker Process Equipment, Inc., Aurora, Ill.

NOZZLES, SPRAY

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.

OIL REMOVAL, RECOVERY

Gale Oil Separator Co., Inc., 52 Vanderbilt Ave., New York 17, N. Y.

PACKINGS, PUMP

Johns-Manville Sales Corp., 22 E. 40 St., New York 16, N. Y.

PAINTS, PROTECTIVE COATINGS

Inertol Co., Inc., 470 Frelinghuysen Ave., Newark 5, N. J.
Koppers Co., Inc., Pittsburgh 19, Pa.

PIPE

Pipe, Asbestos-Cement
Johns-Manville Sales Corp., 22 E. 40 St., New York 16, N. Y.

Pipe, Brass
American Brass Co., Waterbury 88, Conn.

Pipe, Clay
Clay Products Association, 100 N. LaSalle St., Chicago 2, Ill.
W. S. Dickey Clay Manufacturing Co., Kansas City 6, Mo.
National Clay Pipe Manufacturers, Inc., 100 N. LaSalle St., Chicago 2, Ill.
National Fireproofing Corp., Pittsburgh 12, Pa.
Pomona Terra-Cotta Co., Pomona, N. C.
Texas Vitrified Pipe Co., Mineral Wells, Texas

Pipe, Cast Iron
American Cast Iron Pipe Co., Birmingham 2, Ala.
Cast Iron Pipe Research Association, 122 S. Michigan Ave., Chicago 3, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia 5, Pa.

Pipe, Concrete
Portland Cement Association, 33 W. Grand Ave., Chicago, Ill.

Pipe, Steel
Armco Drainage & Metal Products, Inc., 2055 Curtis St., Middletown, Ohio

RECOVERY SYSTEMS, OIL

Gale Oil Separator Co., Inc., 52 Vanderbilt Ave., New York 17, N. Y.

REGULATORS, PRESSURE

Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio
Brown Instrument Div., Minneapolis-Honeywell Regulator Co., 4518 Wayne Ave., Philadelphia 44, Pa.
Pittsburgh Equitable Meter Div., Rockwell Manufacturing Co., Pittsburgh 8, Pa.

PUMPING EQUIPMENT

Pumps, Airlift
Walker Process Equipment, Inc., Aurora, Ill.

Pumps, Diaphragm
Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Hardinge Co. Inc., 240 Arch St., York, Pa.
Marlow Pumps, Ridgewood, N. J.
Yeomans Brothers Co., 1411 N. Dayton St., Chicago 22, Ill.

Pumps, Plunger
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Marlow Pumps, Ridgewood, N. J.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Walker Process Equipment Co., Aurora, Ill.

Pumps, Portable
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Economy Pumps, Inc., Hamilton, Ohio
Marlow Pumps, Ridgewood, N. J.

Pumps, Self-Priming
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Marlow Pumps, Ridgewood, N. J.
Yeomans Brothers Co., 1411 N. Dayton St., Chicago 22, Ill

Pumps, Sewage
American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Economy Pumps, Inc., Hamilton, Ohio
Marlow Pumps, Ridgewood, N. J.
Yeomans Brothers Co., 1411 N. Dayton St., Chicago 22, Ill.

Pumps, Sludge
American Well Works, 100 N. Broadway, Aurora, Ill.
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Economy Pumps, Inc., Hamilton, Ohio
Hardinge Co., Inc., 240 Arch St., York, Pa.
Marlow Pumps, Ridgewood, N. J.
Walker Process Equipment, Inc., Aurora, Ill.
Yeomans Brothers Co, 1411 N. Dayton St., Chicago 22, Ill.

Pumps, Sump
American Well Works, 100 N. Broadway, Aurora, Ill.
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Economy Pumps, Inc., Hamilton, Ohio
Yeomans Brothers Co., 1411 N. Dayton St., Chicago 22, Ill.

Pumps, Vacuum
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Yeomans Brothers Co., 1411 N. Dayton St., Chicago 22, Ill.

RECORDERS

Recorders, Flow

Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio
Brown Instrument Div., Minneapolis-Honeywell Regulator Co., 4518 Wayne Ave., Philadelphia 44, Pa.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.
Pittsburgh Equitable Meter Div., Rockwell Manufacturing Co., Pittsburgh 8, Pa.
Simplex Valve & Meter Co., 6719 Upland St., Philadelphia 42, Pa.

Recorders, pH

Brown Instrument Div., Minneapolis-Honeywell Regulator Co., 4518 Wayne Ave., Philadelphia 44, Pa.

Recorders, Residual Chlorine

Wallace & Tiernan Co., Inc., Newark 1, N. J.

Recorders, Water Level

Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio
Brown Instrument Div., Minneapolis-Honeywell Regulator Co., 4518 Wayne Ave., Philadelphia 44, Pa.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.
Simplex Valve & Meter Co., 6719 Upland St., Philadelphia 42, Pa.

RECTIFIERS

Electro Rust-Proofing Corp., Belleville 9, N. J.

REFRACTORIES

Carborundum Co., Refractories Div., Perth Amboy, N. Y.
Johns-Manville Sales Corp., 22 E. 40 St., New York 16, N. Y.
Norton Co., Worcester 6, Mass.

REGULATORS, GAS PRESSURE

Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio
Brown Instrument Div., Minneapolis-Honeywell Regulator Co., 4518 Wayne Ave., Philadelphia 44, Pa.
Pittsburgh Equitable Meter Div., Rockwell Manufacturing Co., Pittsburgh 8, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

REGULATORS, SEWER

Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.

ROAD SURFACING MATERIALS

Koppers, Co., Inc., Pitttsburgh 19, Pa.

RODS, SEWER CLEANING

Flexible Sewer-Rod Equipment Co., 9059 Venice Blvd., Los Angeles 37, Calif.
W. H. Stewart, Inc., P. O. Box 767, Syracuse, N. Y.

RUST-PREVENTION EQUIPMENT

Electro Rust-Proofing Corp., Belleville 9, N. J.

SAFETY EQUIPMENT, GAS

Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Vapor Recovery Systems Co., 2821 N. Alameda St., Compton, Calif.

SAMPLERS, SEWAGE

Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.

SEPARATORS, OIL AND GREASE

Gale Oil Separator Co., Inc., 52 Vanderbilt Ave., New York 17, N. Y.

SCREEN EQUIPMENT

Screens, Fine

Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Jeffrey Manufacturing Co., 902 N. Fourth St., Columbus 16, Ohio
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

Screens, Mechanically Cleaned

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Jeffrey Manufacturing Co., 902 N. Fourth St., Columbus 16, Ohio
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Walker Process Equipment Inc., Aurora, Ill.

Screens, Vibrating

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Jeffrey Manufacturing Co., 902 N. Fourth St., Columbus 16, Ohio

SCREEN-GRINDER UNITS

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.

Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Infilco, Inc., 325 W. 25 Pl., Chicago 16, Ill.

SEWER CLEANING EQUIPMENT

Flexible Sewer-Rod Equipment Co., 9095 Venice Blvd., Los Angeles 37, Calif.
W. H. Stewart, Inc., P. O. Box 767, Syracuse, N. Y.

SIPHONS, SEWAGE

American Well Works, 100 N. Broadway, Aurora, Ill.
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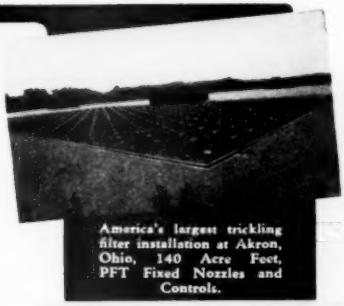

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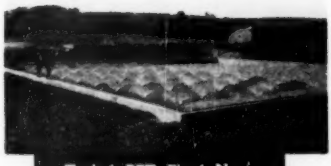

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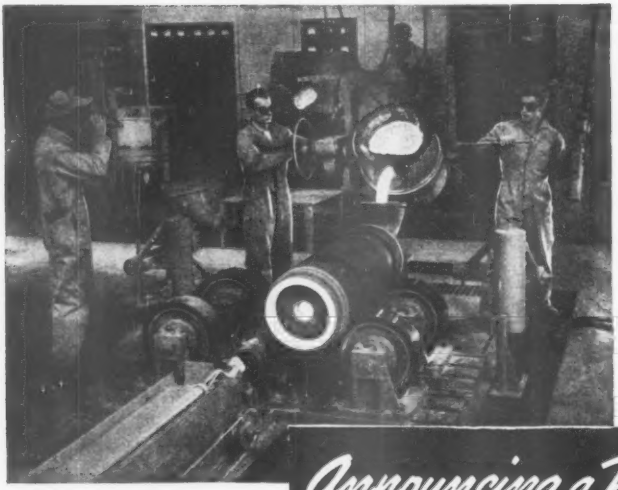

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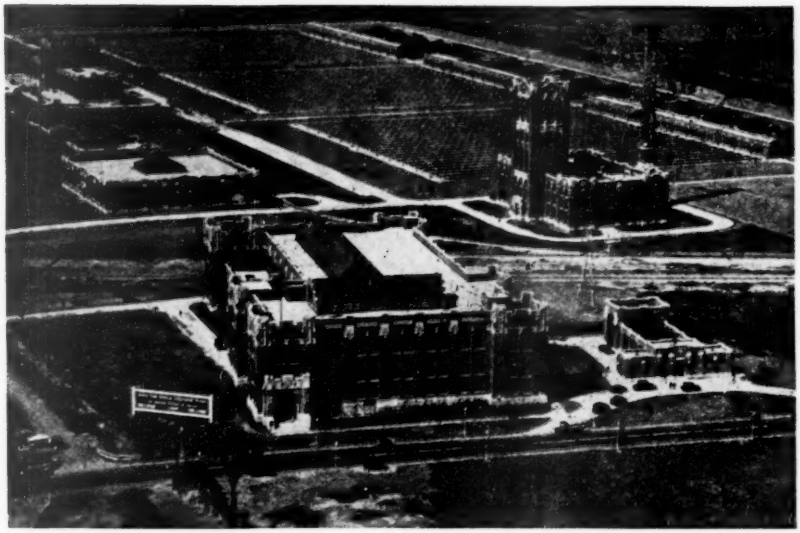

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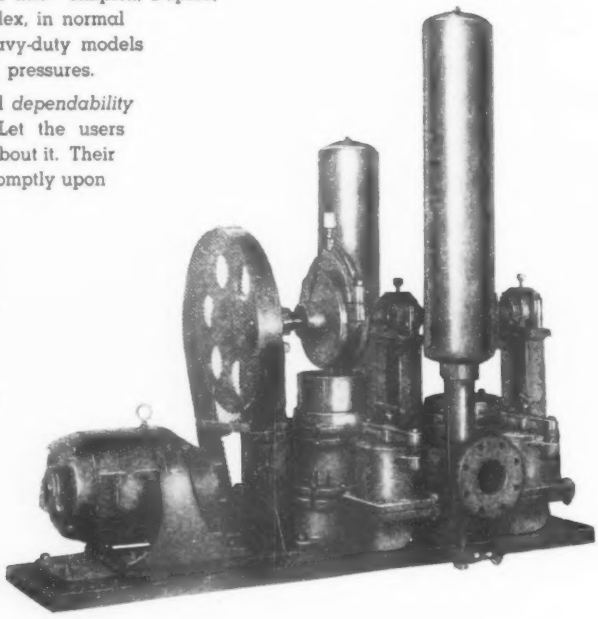

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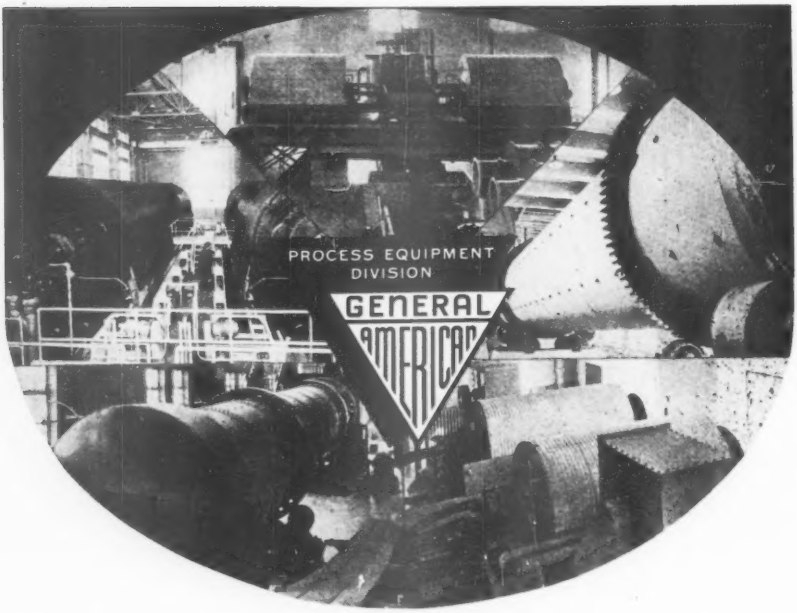

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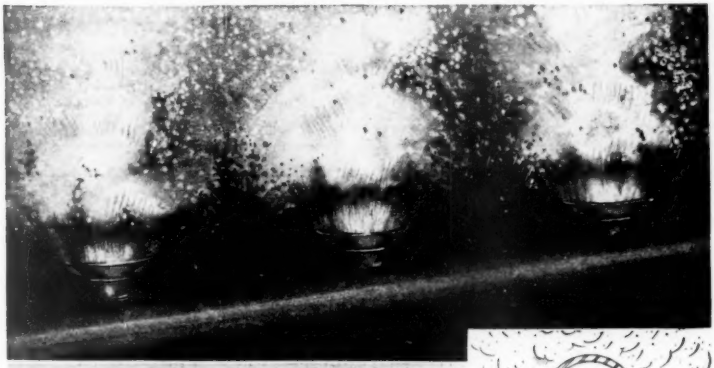

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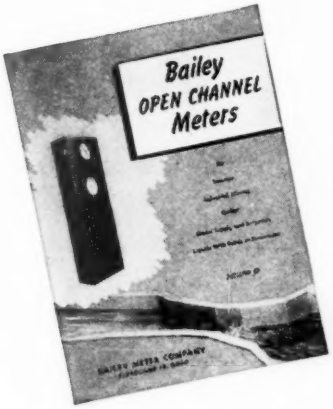

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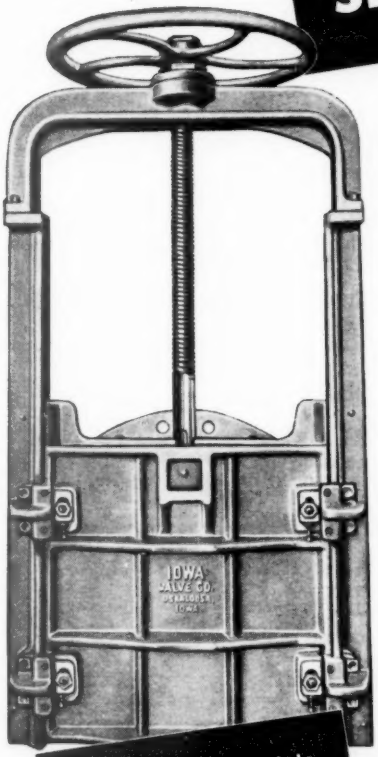

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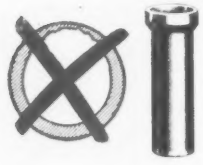
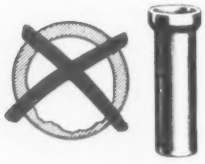


If it's clay pipe

it's proof against chemical disintegration

By its nature, clay is chemically inert. It cannot unite with the acids and alkalis of sewage, no matter how strong they are. It cannot rust or rot. It has the endurance of the earth itself.



If it's vitrified clay pipe

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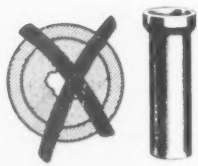
Vitrification at the metal-melting heat of 2200° F welds the particles of clay into a dense, hard, strong unit. Fast-moving particles of grit in sewage can't harm vitrified clay.



If it's salt-glazed, vitrified clay pipe

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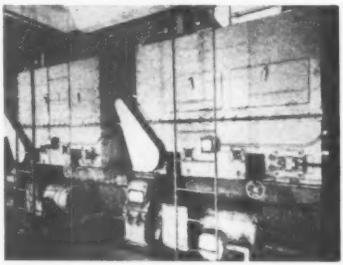

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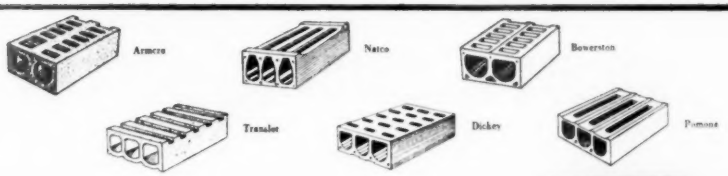

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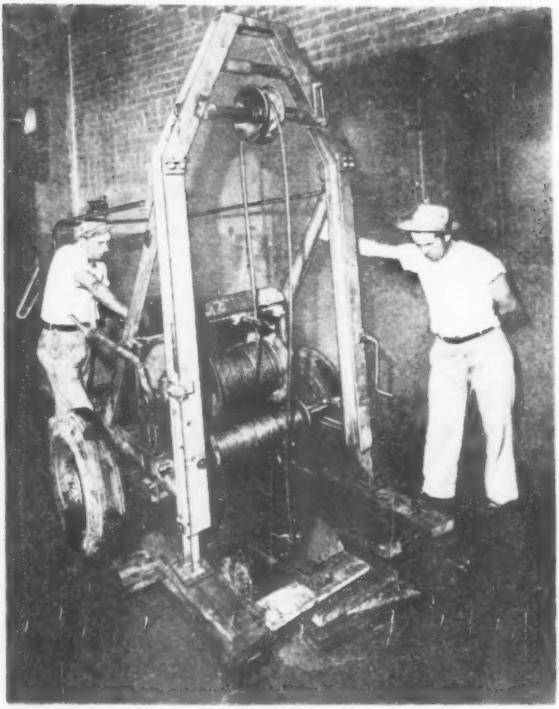

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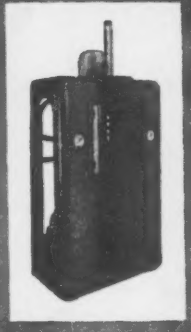

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